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ABSTRACT

This document provides curriculum planners with models of learner outcomes that can be incorporated into a science curriculum and science essential learner outcomes. The first chapter includes a list of educational system values and learner values, philosophy of education, the mission for public education, and learner goals that describe the knowledge, skill, processes, values, and attitudes that a learner can expect to achieve as a result of active participation in K-12 public education. The second chapter provides a preliminary framework for one science education model. Chapter 3 lists science learner outcomes for overarching concepts, basic and integrated process skills, personal needs, science in the world (science/technology/society), and reading and writing in the sciences. The outcomes are cross-referenced with the Minnesota State Board of Education goals, and a development and concept emphasis is listed for each outcome. Chapter 4 explains how to transpose the outcomes into the curriculum. The first part provides a bridge between the rationale for science education developed in Chapter 2 into the basis for curriculum centered around the learner outcomes found in Chapter 3 and also describes instructional practices advocated by science educators. The second part contains questionnaires to assess the condition and determine the relative strengths and weaknesses of the science program. The appendixes, which comprise half the document, contain a variety of evaluation instruments along with some brief descriptive material: multicultural/gender disability/sensitive science education curriculum (checklist); multicultural nonsexist education and science education--considerations; user's guide to a matrix assessment; perceptions of the science program (parent, student, and teacher surveys); science education curriculum (questions to be used by evaluating committees); facilities and laboratory safety (checklist); and learner outcomes--what should be learned (checklist). (17 references) (KR)

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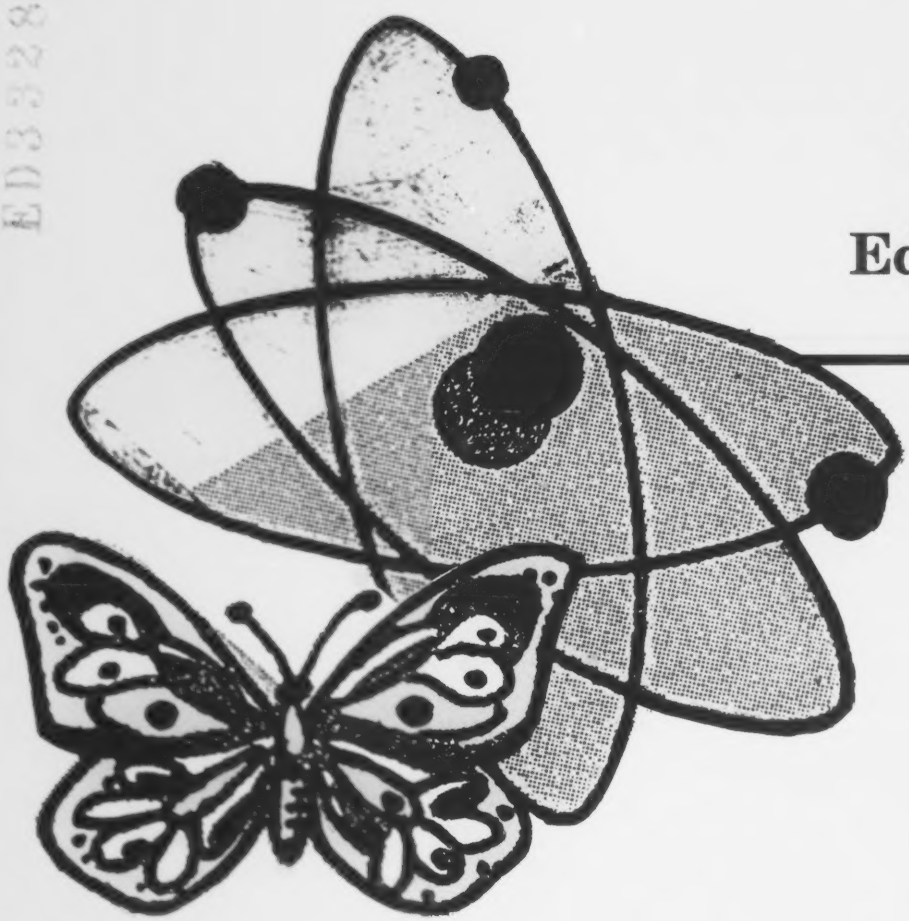
Model Learner Outcomes for Science Education



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MODEL LEARNER OUTCOMES

FOR

SCIENCE EDUCATION

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Chapter 1

Minnesota State Board of Education

Education Values, Learner Values

Philosophy, Mission, and Goals

Chapter 1

Minnesota State Board of Education

Values, Philosophy, Mission, and Goals

School districts nationwide, and certainly in Minnesota, are constantly striving to improve the learning experiences they provide students. The last two or three decades have seen heightened interest in improving all parts of the education process, including appropriate involvement of students, parents, and the community at large.

The documents that constitute the Minnesota Department of Education's *Coordinated Model for Educational Improvement* incorporate many of the concerns expressed and issues addressed by the public, Legislature, and in reports on the state of public education. One of these documents, titled *Goal and Outcome Specification Process*, suggests a set of procedures for appropriate involvement of the public. These procedures include public participation on the development of statements of values, philosophy, mission, and learner goals. These sets of statements are a hierarchy of increasingly specific concepts ranging from values, the most general, to learner goals, the most specific, that give form and direction to public education. Given this hierarchy, staff skilled in subject matter and the profession of teaching can develop very specific learner outcomes for each subject area.

The following sets of statements were adopted by either the Minnesota State Board of Education or the Minnesota State Legislature for two purposes. First, they provide a model for use by communities and school staff as they strive to improve the learning experiences they provide for residents. Second, they are the hierarchy used by Department staff and teams of educators as they develop model learner outcomes for each subject area. The *Mission Statement for Public Education* adopted by the Legislature gives explicit direction to public schools. The State Board Curriculum Rule 3500.1060 adopted February 1990 lists the learner goals which must be incorporated into each district's goal statements. All other parts of this document are models, suggestions for the consideration of residents and professionals in each district.

Education System
Values

We believe the following values are preeminent for the education system. These attributes are to be reflected in all educational programs and operations.

Accountability - A condition in every school whereby each is able to justify its use of public resources by effectively fulfilling its mission of learning.

Effectiveness - A condition in every school whereby each accomplishes its mission at a performance level defined by learners, parents, citizens of the community and state, and their representatives.

Efficiency - A condition in every school whereby each accomplishes the highest possible level of excellence with available resources.

Excellence - A condition in every school whereby the highest possible standards for performance are expected of all students and staff.

Flexibility - A condition in every school which results in meeting the needs of learners through sensitive and creative responses to changing circumstances.

Human Equity - A condition in every school which offers equal opportunity and appropriate individualized support to each staff member in employment and professional growth and to each learner in the educational process. Also, a condition which fully, fairly, and accurately portrays various cultures, races, and genders in the instructional program.

Responsibility - A condition in which the school recognizes that the parent has primary responsibility to assure the child is educated, and in which a partnership exists between the school, community, parent, and the learner to identify the learning goals and needs of the child or adult learner and provide appropriate learning opportunities through which those goals can be met.

Responsiveness - A condition in every school whereby diversity of personal and group needs and aspirations are expected, accepted, encouraged, and routinely addressed.

System Equity - A condition in the education system whereby each school is provided with the resources necessary to assist all learners in achieving excellence.

Wholeness - A condition in every school whereby each gives necessary and appropriate consideration to the potential career needs, spiritual, social, emotional, and physical growth of each learner and staff member as it designs and implements educational programs.

Visionary - A condition in the education system whereby emerging trends which will affect the knowledge and skills required to be a successful adult are examined and the knowledge gained isused to produce appropriate changes in the system's course content, procedures, and goals for learners.

Learner Values

We believe helping students develop the following values is a primary purpose of education.

Accountability - A quality in individuals whereby each knows, understands, and accepts the impact and consequences of personal actions and decisions.

Citizenship - A quality in individuals whereby each has an understanding, appreciation, and support of the institutions of American government and society, and a willingness and ability to participate in the democratic process and in socially beneficial service activities.

Compassion - A quality in individuals whereby each is sensitive to the conditions affecting the lives of others and each has the commitment to assist others when appropriate and possible.

Competence - A quality in individuals whereby each attains maximum levels of knowledge, skill, and affect commensurate with his or her potential.

Cooperativeness - A quality in individuals whereby each interacts with others in a manner that mutually benefits all participants in the interaction.

Creativity/Flexibility - A quality in individuals whereby each acts or expresses self in new, improved, or unique ways.

Ethics - A quality in individuals whereby each displays consistent personal and professional integrity and an acceptance of the responsibility to act for the benefit of all learners.

Honesty - A quality in individuals whereby each is fair and straightforward in the conduct of human interaction.

Learning - A condition in individuals whereby each continually strives throughout life to learn more and to increase personal levels of fulfillment and competence in human endeavors.

Problem Solving - A condition in individuals whereby each has the ability to identify, frame, and propose new, improved, or unique solutions to existing and emerging problems.

Responsibility - A quality in individuals whereby each strives to fulfill the obligations of economic self-sufficiency and active commitment to the common good of society.

Self-Acceptance - A quality in individuals whereby each has a positive self-image, through assertion of rights, holding personal, physical, and emotional well-being as an ideal, accepting personal talents with humility, and personal limitations with the resolve to improve where possible and accept where necessary.

Spirituality - A quality in individuals whereby each recognizes and accepts the importance of nurturing one's inner spirit, that creative force that transcends the human and the material.

Thinking - A condition in individuals whereby each continually strives to improve personal skills for mental manipulation of sensory perceptions to form knowledge, thoughts, reason, and judgments.

Minnesota State Board of Education
Philosophy of Education

We Believe . . .

. . . . Every person can learn.

. . . . Learning is a lifelong process.

. . . . Every person must understand and accept self before he or she can become a contributing member of society.

. . . . Each person has gifts which the education program must seek, identify, and help to maximize.

. . . . Advancement of the human race requires individuals who are honest, responsible, compassionate, cooperative, creative, and competent.

. . . . The state and local communities have a shared responsibility to assist each person in learning.

. . . . Each community has a shared responsibility with parents for meeting the needs of each child.

. . . . The community and its school system must continually look to and strive to meet the future education needs of society.

. . . . The education system must assist each person to become functional in an increasingly global and interdependent world.

. . . . The education system must lead people to value and accept a wide diversity in human behaviors, sophistication, and values.

. . . . The education system must maintain high standards for responsiveness, human equity, and system equity in the provision of educational opportunities.

. . . . Decisions regarding planning, implementing, and maintaining learning opportunities must be vested as close to the individual learner as efficient use of public resources allow.

. . . . School systems must implement programs that stress the intellectual development of each learner in concert with the spiritual, social, emotional, and physical development of the learner.

. . . . School systems must model and nurture creativity in learners.

. . . . School systems must maintain opportunities for all learners to develop competence in personally selected areas of human development.

. . . . Professional educators have a responsibility to remain current with evolving knowledge about human growth and development, learning theory, and knowledge of subject matter.

.... Professional educators and elected or appointed education policymakers have responsibility to account to the public for the excellence of their efforts.

.... Professional educators and elected or appointed education policymakers have responsibility to use public resources prudently and efficiently.

.... Staff employed in schools must model the behaviors they are assisting learners to develop.

Mission for Public Education

As adopted by the Minnesota Legislative Commission on Public Education and enacted into law, Chapter 240, Laws of 1985

The purpose of public education is to help individuals acquire knowledge, skills, and positive attitudes toward self and others that will enable them to solve problems, think creatively, continue learning, and develop maximum potential for leading productive, fulfilling lives in a complex and changing society.

Mission of the Minnesota State Board of Education

The Minnesota State Board of Education will provide the vision, advocacy, and leadership to improve significantly the quality of education throughout the state.

Mission of the Minnesota Department of Education

The Minnesota Department of Education provides leadership, service, and regulation to maintain and improve an equitable, uniform, and quality system of public education for all learners.

The Department provides leadership as an advocate for education by defining quality education and by seeking the resources necessary to meet the needs of all learners.

The Department provides service through informational and technical assistance that will improve the productivity and performance of students and staff, and provide opportunities for the development of the potential of all learners.

The Department regulates education by maintaining, interpreting, and enforcing Minnesota State Board of Education rules, and state and federal laws.

Minnesota State Board of Education

Learner Goals

Learner goals are a series of statements that describe the knowledge, skill, processes, values, and attitudes that a learner can expect to achieve as a result of active participation in K-12 public education. They are based on the presumed current and future intellectual, social, emotional, physical, and career/vocational needs of students and adults in contemporary society.

Each district shall use the learner goals contained below as the basis for defining program-level learner outcomes that are directly reflected in the district's course and program offerings.

A. To effectively participate in learning activities, each learner will:

1. master reading literacy to gather information and data, gain perspective and understanding, and as a leisure activity;
2. master writing to explain, describe, and express a point of view and feelings;
3. master listening to gather information and data and gain perspective and understanding;
4. master speaking to explain, describe, express a point of view and feelings, and to discuss an issue;
5. master numerical literacy to apply mathematical functions to life situations;
6. master the use of a variety of tools, including electronic technology, to enhance learning;
7. master viewing and observing to gather information and data, and gain perspective and understanding; and
8. apply skills in self-expression through visual and performing arts.

B. To provide a foundation for meaning in life, each learner will accumulate and apply knowledge and develop the understanding to:

1. participate in lifelong learning;
2. live within local, state, national, and world political and social structures;
3. examine personal beliefs and values and their relationship to behavior;
4. make ethical and moral decisions;

5. be a responsible citizen of the community, nation, and the world;
6. practice stewardship of the land, natural resources, and environment;
7. know the impact of human life on nature and the impact of natural phenomena on human life;
8. express self through artistic creation;
9. know career options and the general education requirements for each;
10. know world and national economic conditions to make informed decisions on consumer products, occupations and career needs, and use of resources;
11. select or prepare for a series of occupations that will personally satisfy and suit one's skills and interests;
12. manage personal affairs;
13. understand the physical world using systematic problemsolving strategies:
14. communicate and relate effectively in a language and about a culture other than one's own; and
15. know the importance of geographic location in the functioning of contemporary society.

C. To think, decide, resolve issues, and meet needs creatively, each learner will be able to:

1. compare, differentiate, and relate information and facts and apply knowledge;
2. combine various facts, situations, and theories to formulate new and original hypotheses or to develop new solutions;
3. critique and make judgments about materials, conditions, theories, and solutions;
4. generate and value creative alternatives; and
5. apply the concepts and processes of science.

D. To value, understand, and accept human interdependence, each learner will be able to:

1. seek interactions and feel comfortable with persons who are different in race, religion, social level, or personal attributes;
2. understand the basic interdependence of the biological and physical resources of the environment;
3. understand the interrelationships among complex organizations and agencies in modern society;

4. understand how the citizens of the United States are geographically and socially connected to people and places in other parts of the world.

E. To value, understand, and accept the diversity of humankind, each learner will be able to:

1. base actions and decisions on the knowledge that individuals differ in many ways;
2. base actions and decisions on the knowledge that values and behaviors differ from one social group to another;
3. base actions and decisions on the understanding that lifestyles and behaviors reflect the value system of the societies in which they were learned;
4. judge other's actions with an understanding of the personal and social context of that action;
5. accept that there is more than one way of being human;
6. base actions and decisions on the understanding that as individuals move from one society to another they can learn lifestyles and can learn to behave appropriately in different social contexts; and
7. act on the belief that human behavior is influenced by many factors and is best understood in terms of the context in which it occurred.

F. To address human problems through group effort, each learner will develop the knowledge, skills, values, and attitudes essential to:

1. act in accordance with a basic ethical framework incorporating the values that contribute to successful community life such as honesty, fairness, compassion, and integrity;
2. understand the importance of working in groups to achieve mutual goals; and
3. be able to provide leadership in resolving personal and societal issues.

G. Each learner will be able to effectively resolve conflicts with and among others by:

1. assuming responsibility to form productive and satisfying relationships with others based on respect, trust, cooperation, consideration, and caring for other persons;
2. acting on the belief that each individual has value as a human being and should be respected as a worthwhile person; and
3. resolving conflict in the manner most beneficial to society.

H. Each learner will be able to act on contemporary events and issues with a perspective of their historical origins:

1. understanding the origins, interrelationships, and effect of beliefs, values, and behavior patterns in world cultures;
2. understanding one's own culture and historical heritage through the literary, aesthetic, and scientific traditions of the past;
3. being familiar with the ideas that have inspired and influenced humankind; and
4. understanding the manner in which heritages and traditions of the past influence the direction and values of society.

I. Each learner will develop a positive attitude toward self, demonstrated through:

1. a feeling of positive self-worth, security, and self-assurance;
2. a willingness to live with one's strengths and weaknesses;
3. a basic understanding of one's own body, its systems and physiology, and a positive attitude toward one's own physical appearance;
4. understanding that efforts to develop a better self contribute to the development of a better society;
5. understanding that self-concept is acquired by interaction with other people; and
6. appropriate control or release of emotions.

J. To set and achieve personal goals, each learner will develop the ability to:

1. select appropriate personal learning goals;
2. make decisions about one's life;
3. plan, act, and organize to realize one's goals;
4. accept responsibility for personal decisions and actions;
5. work now for goals to be realized in the future; and
6. select viable alternatives for actions in changing circumstances.

K. To cope with change, each learner will develop the ability to:

1. initiate appropriate change while respecting existing structures and concepts;
2. tolerate ambiguity;
3. understand that coping with change is a lifelong process;

4. understand and accept the changing nature of work and the potential need to change careers several times;

5. use career information and counseling services to make informed and satisfying vocational choices; and

6. understand that all knowledge is tentative and that as new discoveries are made the knowledge base grows.

L. To lead a healthy and fulfilling life, each learner will:

1. assume responsibility for one's own physical and mental health and safety by establishing a daily regime of health behaviors that will maintain mental and physical health and motor fitness;

2. make informed decisions about health products and services;

3. make a lifestyle that promotes healthful family living;

4. understand public health measures and their effect on the individual, family, community, and environment; and

5. be able to enjoy play-skill activities that include understanding, cooperation, accepting rules, controlling emotions, following group process, and acquiring self-satisfaction.

M. To lead a productive life and actively contribute to the economic wellbeing of our society, each learner will develop the work readiness skills of:

1. applying the basic skills of communications, computation, and scientific principles to real-life situations in a technological society;

2. defining and interpreting the nature of the work force in terms of one's own challenges and opportunities;

3. leadership and citizenship necessary to succeed as an active agent in a changing work force;

4. understanding employment opportunities, job seeking and keeping, and specific work as they relate to transition from school to economic productivity;

5. developing pride in good work and expecting quality in products and services; and

6. adopting a positive attitude toward work, including the acceptance of the necessity of making a living and an appreciation of the value and dignity of work.

Chapter 2

Science Education

Introduction

Goals

Program Level Learner Outcomes

CHAPTER 2

INTRODUCTION

> *What we want most of all in terms of science literacy is an educated public that shows a sense of proportion about the scientific endeavor... What we are looking for, then, is a situation in which lay people demonstrate knowledge of both the potentialities and the limitations of science--what people in less scientific times called wisdom.*
>
> *Drew Christianson, Education in the 80's: Science.*

While it may be chauvinistic to equate scientific literacy with wisdom, after all, science is just one aspect of a balanced curriculum, we would like to think the author was saying that science, when taught correctly, provides skills and strategies for solving everyday problems. Moreover, it allows persons to understand themselves as well as their immediate environment in a way that was impossible even 50 years ago.

This document provides a preliminary framework for one science education model. It attempts throughout to answer questions and provide basic direction that leads to scientific literacy. It addresses the following questions: What is science? What are the major concepts of science? How is science applied to everyday living? What is the connection of science to technology and technology to science? How does science affect our personal lives?

Wisdom is the aim of all educational efforts. Science, if taught correctly, will bring to bear skills, and concepts that foster good judgment and understanding.

One major problem facing teachers of science is determining what constitutes scientific literacy. This issue can be summarized in the following questions: What competencies and willingness should a student have to use scientific or technological information to fully and effectively realize citizenship in a democratic society? What kinds of science will meet the personal and career needs of students? What can science education contribute to the enlightment and understanding of values that are held by a society that is highly mobile and culturally diverse?

Beyond the purposes of science education implied in these questions is the issue of what students should know to keep our state and country competitive. Time and time again international tests and assessments indicate that students in this country do much worse than their counterparts overseas. Furthermore, these differences increase as time in school increases.

How can this happen when so many resources are dedicated to educate our children to live in a modern society? If we are to believe the myriad reports that address the quality of science education, we must conclude that the problem is systemic. Science textbooks increase in size with each edition to the point where there simply is too much to be covered in any one year and, even more importantly, many of the topics presented are not developmentally appropriate for the intended age group--leptons at grade six, for instance. We must answer the question, "How can science be structured and sequenced when it really is a collection of subdisciplines, each having its own protocols?"

Recent national projects such as Project 2061 have taken the position that it is impossible to teach it all. There is simply too much to learn, and there is no scope and sequence that is accepted by all science educators. Instead, they have opted for a "**less is more approach.**" Since one cannot teach "**the book,**" then what is clearly called for is a "**sequence**" that is built around fundamental concepts, process skills, and attitudes that pervade all of science, and that are common to all of its subdisciplines. Students will not memorize the facts of science–there are far too many. Instead, students will be introduced to a limited number of concepts, skills, and attitudes which will be constructed gradually, grade by grade, reminiscent of the upward-moving spiral curriculum.

WHY SCIENCE?

Science is a critical component of the school curriculum for many intertwined reasons. They include the very basic motivation to understand the universe as well as the know-how to understand, and not to be bewildered by commonplace events in nature, new technologies, knowing how the scientific-technological system works, and how to make it work.

Furthermore, many of our social problems have roots which are found in science and technology. These include chemical fertilizers, nuclear energy, genetic engineering, population growth, and the productivity of the natural systems that undergird the economy.

In a democratic society, such problems require all of us to be actively involved if we are to successfully resolve them. Science also has contributions to make to basic education and even to success in the workplace for those high school graduates who do not go on to a four-year college--the largest segment of the American workforce. There are many reasons for teaching and learning science, including:

Preservation of our democracy requires an informed, active, and thinking electorate.

a) **Science as a way of knowing**. There are a variety of ways of knowing about the world--ways by which we satisfy our curiosity about it. Today, science is one of the preeminent ways to experience and know the world. Science began by refraining from asking general questions such as: How was the universe created? What is the essence of life? Scientists ask limited questions, such as: How does an object fall? How does water flow in a tube? Thus, in place of asking general questions and receiving limited answers, they ask limited questions and find general answers. It remains a great miracle that this process has succeeded and that the answerable questions became gradually more and more universal.

b) **Basic skills.** In *Science Teaches Basic Skills*, Kenneth R. Mechling and Donna L. Oliver (1983) point out that "Science content is basic because it is part of kids' everyday lives." Project Synthesis, a National Science Foundation-supported study, by Harms and Yager (1981), identified four areas in which science touches children's lives in significant ways. Besides helping students learn scientific ideas and processes, it meets personal needs, helps them become informed citizens, and assists them in making career decisions.

c) **Recruitment of the young**. In the last several hundred years, there has been an increase in numbers of scientists and scientific specializations. If science is to continue to prosper, attention must be paid to developing and nurturing an interest in science as a career.

d) **Welfare of society**. We have a crucial dependence upon science, e.g., in agriculture, medicine, industry, government, and the military. "Our aim in teaching basic science," according to David Hawkins, "should be to prepare all youngsters for eventual participation in the democratic discussion and reordering of ends; the narrowing, even the failure to broaden basic science education, creates scientific and technological oligarchies, while the rest of us tend to become incompetent for democratic rule, to become--in the language of Toynbee--a cultural proletariat." (Hawkins, 1983)

e) **Science complements other curriculum areas**. Many elementary teachers feel they lack both time and training to do an adequate job teaching science. Research findings, particularly at the elementary and middle school levels, show that science education contributes to the development of basic skills of language, reading, arithmetic, perception, logic, and creativity. Science is far too important to omit. Instead, science should be integrated with other curriculum areas: mathematics, art, language arts, and social studies.

f) **Regaining contact with the world of experience.** Richard D. Logan and George T. O'Hara (1982) call attention to the influence of recent lifestyle changes that "have led to an orientation away from before-after, cause-effect reasoning" both short-term and long-term, and away from analytical observations of events of the world. "Science instruction encourages students to inquire, to hypothesize, to ask questions, to describe phenomena, and to list the possible factors involved."

CURRICULUM ISSUES

In this chapter, the forces that ought to shape the current school science curriculum, content and instruction are discussed. Its content is intended to provide a basis for methodology and a rationale for a constructivist curriculum design. Moreover, both new, and "tried and true" methodologies are reviewed. It is hoped that this section will provide curriculum design committees (PER review committees) with the background and rationale they need to assure that local efforts are not only well planned, but provide data for evaluation and characteristics of a well-taught science program.

In the traditional view of curriculum and instruction, students passively absorb established facts, skills, and concepts. Constructivism sharply contrasts with this view. Attributes of science learning from a constructivist perspective include: 1) knowledge is actively created by learners, not passively received; 2) learners create new science knowledge by reflecting on and integrating it into what they know; 3) there is not a single, right reality, only individual interpretations of the world; 4) learning is a social process involving explanation and negotiation of ideas; and 5) learners bring their own ideas to science lessons and must be given all opportunity to express them. (Clements and Battista, 1990)

What is Science?

The debate concerning the nature of science, its guiding philosophies, history, practices, limits, and the role that concepts and conceptual schemes play, has dramatically increased, particularly in the last two decades. In this brief chapter, it is impossible to summarize this body of research in a manner that accurately reflects the diverse ideas of American and international scientists. Instead, the discussion will be limited to ideas and concepts that seem to be without controversy, and which appear to be accepted by scientists, science educators, and classroom teachers.

Simplistic notions of the nature of science abound. Good teachers work to correct misconceptions about scientists and science.

When about sixty ninth-graders were asked: "What is science?" their responses included the following:

1. Cold, objective facts that are somehow out there, external of humans, waiting to be discovered. Science is a collection of facts to be memorized.
2. Science has a special way of arriving at the truth, a stepwise method, and only this "scientific method" is used to establish truth.
3. Scientific truth is value free, essentially changeless and infallible.
4. Scientists are cool, unemotional, and impersonal.

In contrast to this image of science is the actual experience of scientist Stephen Stanley. In 1973, Stanley provided an explanation for one of the great puzzles of paleontology: the proliferation of species at the beginning of what geologists call the Cambrian period, the Cambrian explosion of life. Using data from many contemporary field studies in ecology, Stanley assumed the appearance of new life forms that fed on preexisting grassy abundant forms of life. These grazers or croppers allowed ever new forms to survive the competition from the previously dominant ones, which in time resulted in new grazers. Stanley offered many reasons in support of his theory. Stephen Jay Gould notes that they "do not correspond to the simplistic notions about scientific progress that are taught in most high schools and advanced by most media. Stanley does not invoke proof by new information obtained from rigorous experiment. His second criterion is a methodological presumption, the third, a philosophical preference, the fourth, an application of prior theory. Only Stanley's first reason makes any reference to human judgment and ingenuity upon all its proceedings. It is, after all (although we sometimes forget it), practiced by human beings." (Gould, 1977)

SCIENCE IS MORE THAN FACTS

In the NOVA television program, "The Pleasure of Finding Things Out," the late physicist Richard Feynman described the difference between knowing facts, and understanding the source of the fact. He had this to say about two kinds of walks in the woods, those he took with his father and walks other children took with their fathers.

"All the kids were playing in the field and one kid said to me, 'See that bird, what kind of bird is that?' And I said, I haven't the slightest idea what kind of bird it is. He says, 'It is a brown-throated thrush, or something. Your father doesn't tell you anything.' But it was the opposite; my father had taught me, looking at a bird he says, 'Do you know what that bird is? It's a brown throated thrush--but in Portugese it's a--, in Italian it's a--. He says, In Chinese, it's a--, in Japanese, a--, etc. Now, he says, you'll know absolutely nothing whatever about the bird. You only know about humans in different places and what they call the bird. Now, he says, **'let's look at the bird and what it's doing'** (emphasis added)."

Perception is the way we understand the world. But every child has his or her own private perception. Part of good science teaching is to find how those children perceive their environment.

It is true that science has its facts, e.g., the earth does revolve around the sun. But what is more important to know is **how** we know that. What are the reasons we accept it? This is especially true for young children, because what they observe seems to run contrary to the facts. In the words of John W. Renner, "Science is not a collection of facts, it is a process of extracting meaning..." (Renner, 1982)

Science is not a set body of knowledge or restricted as it once was to the "natural sciences," the science of nature--the traditional and narrow disciplines of physics, chemistry, geology, and biology. As scientists have studied the universe and recognized its complexities, many kinds of science have developed. The result is that for every science there is an established body of knowledge that includes the development of processes for doing that science as well as an independent community of men and women who do science and organize knowledge into coherent frameworks known as theories.

COMPONENTS OF SCIENCE EDUCATION

The domain of science includes six components that are the basis of scientific literacy. These components comprise the essence of *Model Learner Outcomes for Science Education*. The following components are the "core" of science. When one or more are missing from instruction, curriculum and scientific literacy are compromised.

Nature of Science. There are multiple meanings associated with the term "science." Not all chemists or biologists, for example, have the same notion of what "science" is. There are some necessary criteria that make it possible to characterize science. Science is first and foremost a human enterprise. Its methods and concepts evolve as the scientific community evolves and grows. Science is an integral part of the society and its mores. Of all the aspects of science that are taught as a regular part of the accepted curriculum, this aspect is ignored the most.

"...Out of all the possibilities, what knowledge, skills and habits of mind should all Americans have by the time they leave school ... This deceptively easy question has no easy answer..."

Science For All Americans, Project 2061.

Key Concepts of Science. A relatively small number of concepts are pervasive throughout most, if not all, of the various specialized science areas. They comprise the building blocks from which the conceptual structures of science law, principle, etc. are built. The overall quantity of concepts can be kept to a workable number by integrating certain concepts with others.

Processes of Science. In the 1960s, the intellectual processes of science were recognized as legitimate content for science learning. These comprise the hierarchy of how scientists, or anyone else for that matter, solve problems. In simple language, process is the difference between knowing what a bird is called, and discovering what the bird is like. Within certain limits, the processes of science help us to know the precision of our knowledge.

Applications of Science. One of the major purposes of science education is the development of informed citizens who can deal with social problems rooted in science, technology, and society (S/T/S). One can only deal with societal problems that science and technology impose by knowing what the tradeoffs are, and, as an informed electorate, making appropriate choices. S/T/S is essentially science for the citizen. It is one area where students can see how science touches their daily lives, and how it is applied, as well as the moral dilemmas it may present. S/T/S issues are not limited to our state or nation, they are truly international and have global consequences.

Science for Personal Needs. Science and technology influence all of us. The processes of science provide skills that students can use in making everyday decisions. More than that, a knowledge of science and of one's self makes for a healthier and more informed citizen; a citizen able to discuss problems from more than one point of view; and a citizen who is capable of making decisions that are affected more by sound reasoning than by sound bites.

NATURE OF SCIENCE

We live in a scientific culture, but that does not mean we understand much of the science that underpins it. Why should students know the scientific basis for our culture? In a provocative essay, Kenneth Prewitt suggested a reason. It is found in the term "savvy." "A savvy person," according to Prewitt, "has those skills and insights that make for survival and success in what would otherwise be bewildering and intimidating situations." (Prewitt, 1985)

As knowledge and technology burgeon, the world can become a bewildering and confusing place. "Experts" tout opinions and statistics, often disagreeing, but using the same numbers to support their views. What are the implications of global warming for agriculture? How serious is the pesticide problem? Literacy about science reduces some of the confusion about our culture. It is empowering to know the rules to know enough to see the patterns and to speak the language–if not like a native, then well enough to be able to get by and make informed decisions.

In this spirit, a scientifically literate person understands the following about the nature of scientific knowledge:

a) ALL SCIENTIFIC KNOWLEDGE IS TENTATIVE

–Judgment in science can never be final or absolute.
–The data of science must be regarded as provisional and subject to change as new evidence is discovered.

b) THE KNOWLEDGE OF SCIENCE IS PUBLIC

–Science is not a private matter; science knowledge is shared and critiqued with other scientists and the public at large.
–The work of science is open to and thrives on scrutiny.
–The status of scientific knowledge is earned by convincing others of its validity.

c) SCIENTIFIC KNOWLEDGE IS REPLICABLE

–When an experiment is repeated by another person, there is a reasonable expectation that similar results will be obtained, providing the experimental conditions are the same.
–Every tenet, principle, method, or explanation is open to investigation, or it may not be associated with science. There are no "givens."

d) SCIENCE IS PROBABILISTIC

–Statements in science have only probabilistic, not exact information. In other words, truth is approached by closer and closer approximations, but may never be absolutely achieved.
–The probabilistic nature of science imposes certain qualities on the conclusions drawn in the process of interpreting data, embodied in the notions of "on the average."

e) SCIENCE IS THE PRODUCT OF HUMAN ENDEAVOR AND CULTURE

--The construction of scientific knowledge is active, creative, rational, emotional, and pragmatic. In other words, scientists are human beings.
–Science is a knowledge-making process.
–Science cannot segregate itself from society; science and society are interrelated.
–Science continues to exist for a variety of **non-scientific** reasons--commercial, strategic, bureaucratic, political, and social.
–Human prejudice may **retard** or **block** insightful new knowledge because it may run contrary to established norms, conventions, or protocols.

'The distinctive character of our own time lies in the vast and constantly increasing part which is played by natural knowledge. Not only is our daily life shaped by it, not only does the prosperity of millions...depend upon it, but our whole theory of life has long been influenced, consciously or unconsciously, by the general conceptions of the universe, which have been forced upon us by physical science."

--Thomas Henry Huxley, 1880

f) SCIENCE IS HISTORIC

--Scientific knowledge of the past has provided the basis for today's knowledge, which in turn, will provide the basis for tomorrow's knowledge.
--Science knowledge of the past should be viewed in its historical context and not judged on the basis of our present knowledge.

g) AMONG THE WAYS OF KNOWING, SCIENCE IS DIFFERENT

--Natural events are determined or caused.
--Scientific knowledge is validated by consensus, i.e., by publication of results, debate, and criticism by peers, the reported experiments must be **reproducible** by others.

KEY CONCEPTS

There are at least two ways to identify and think about scientific concepts. One is idiosyncratically, i.e., the unifying concepts within each particular discipline of science. Another, and the one that has been chosen here, is to identify the key, overarching concepts of science which represent a **minimal** conceptual core of science knowledge. These are concepts that are considered common to all branches of science.

Concepts that are common to all branches of science are the primary goal of a balanced science curriculum

In the idiosyncratic example, the result is an intractable array of concepts; long lists that describe the various disciplines within science. These leave the students without a sense of how the parts of science fit together. In the minimal example, an attempt is made to cut across the disciplines of science, and to identify the key content dimension--the minimal usable core of science literacy.

Identifying the minimal content or conceptual core of science knowledge has been, and will continue to be, a persistent problem in science education. Those opposed to such approaches argue that there are few common denominators across disciplines. Concern is also expressed that science is a more variable enterprise than a unitary scheme can express. Finally, there is concern about the level of generality of such unifying concepts, i.e., they are too abstract to be meaningful or relevant to elementary and secondary students.

There are also several powerful counterarguments. One is that, while in practice, many concepts can be identified. The key concepts represent a general class of related concepts.

This implies:

1. a hierarchy of concepts
2. a framework within which to understand the content of science knowledge
3. that learners construct understanding based on a knowledge of relationships and prior knowledge; and
4. levels of development regarding understanding of particular concepts.

A WORKING LIST OF KEY CONCEPTS

The key concepts of science were identified by a Minnesota Department of Education learner outcome committee comprised of science educators (see Acknowledgements). The concepts that are listed here are not original; they have been selected from several sources. When changes were necessary, those changes consisted of simplifying complex ideas, and defining them in ways that are understandable.

The American Association for the Advancement of Science (AAAS) in its publication, *Science For All Americans*, identified its own list of common themes: systems, models, constancy, patterns of change, evolution, and scale. Although the AAAS version is shorter than the one below, the careful reader will soon discover that most, if not all, of the Minnesota themes that were identified are represented as subcategories of the AAAS themes. This was done because the learner outcomes committee felt that the AAAS definitions for the major themes were too inclusive. For example, the learner outcome committee used change as a major heading with evolution as a subset rather than separating them into two categories: patterns of evolution and change.

All of the concepts, processes, and attitudes in this chapter are found in the program level learner outcomes adopted by the State Board of Education in February 1990, Curriculum Rule 3500.1075.

The most difficult challenge for science educators and the public is the understanding that science literacy means more than memorizing and regurgitating facts of chemistry, biology, and physics.

CAUSE/EFFECT

Some of the criteria of cause and effect include:
- that cause and effect are always present in the event
- that cause and effect have a sequential order
- that cause and effect have a statistical probability
- that a cause may have to reach a threshold level before the effect is observed
- that a change in the magnitude of the cause may produce a change in the magnitude of the effect.

CHANGE

Everything is in the process of becoming either different or something else. The rate at which it happens varies from very fast to very slow, so slowly that it may be unnoticed. Many changes involve several states or mechanisms.

Change is described by comparing the final state of the system to the initial state of the system.

CYCLE

The apparent pattern in which certain events or conditions seem to be repeated at regular intervals or periods: a clock exemplifies the condition in the sense that it measures time under a given set of environmental conditions.

Cycles often work together as a dynamic, integrated, and interacting whole, for example, the fundamental biogeochemical cycles–the rock cycle, the water cycle, the nutrient cycle, and the CO_2 - O_2 cycle. A common example is seasons.

ENERGY/MATTER

Energy is a quantity having the dimensions of a force times a distance, which is conserved in all interactions. It exists in many forms and can be converted from one form to another.

Matter is anything which has mass and can exist ordinarily as a
solid, liquid, or gas.
Matter is the "stuff" of which all things are composed.
Energy has the ability to cause change.
"Energy has mass and mass represents energy." Einstein

The story of energy-matter is one of flow and change, governed by strict rules.

EQUILIBRIUM AND HOMEOSTASIS

A state of affairs in which changes (or tendencies to change) occur in opposite directions, happen at equal rates, or are of the same magnitude.

A state where forces oppose in equal and opposite directions, or where concentrations or reactions are in balance.

When observable changes no longer occur in a reacting system.

In living organisms, homeostasis is the mechanism which counters a tendency toward equilibrium, using feedback mechanisms which monitor the current state and stimulate appropriate activity.

INTERACTION

A situation in which two or more things affect each other.

FUNDAMENTAL ENTITIES

Basic units of any system, biotic, or abiotic. To alter basic units is to change their nature–molecule to atoms, compound to elements, cells to nonliving organic entities.

PROBABILITY

Science can reach general conclusions only in the form of a "bet"...

A mathematical basis for prediction that is predicated on a large number of trials. No probability can ever be exactly known because no action can be performed an infinite number of times. Therefore, science can reach **general** conclusions only in the form of a "bet" about what should be there in the long run. Probability is always measured on a scale marked zero at one end--absolute impossibility, and one at the other--absolute certainty.

PATTERNS AND SYMMETRY

Things exist in balanced proportions - a sense of order and regularity. Our aesthetic appreciation of symmetry may stem from its vital role in nature.

SYSTEMS

A group of things or events which can be defined, at least in part, by boundaries that one person can communicate to another, and which enable it to be analyzed more effectively.

A group of related objects that form a whole. Systems are often selected because the objects interact or have the ability to do so.

Systems can consist of subsystems.

KEY PROCESS SKILLS OF SCIENCE

Process skills are the problem-solving skills of science. These skills constitute what others call higher order thinking skills. In learning what scientists do, one thing that students should do is to become highly involved in **using** the processes of science. Such activities reflect the nature of science and the typical activity of scientists. Process skills provide students with ways to find things out about the world. They accomplish this by observing, by classifying, by collecting and interpreting data, drawing conclusions from the data, and (sometimes) using what has been learned as the basis for new investigations.

Process skills are not independent of content, indeed they are always dealt with in terms of scientific content, and would be useless without such a context. For the purposes of this document, process skills are divided into two classes, basic and integrated processes. The basic processes provide the foundation for the more complex, integrated processes. Both are necessary to solve scientific problems.

Give me a fish and I will eat for a day; Teach me to fish and I will eat for a lifetime.

There are many reasons for integrating process skills into the science curriculum. Some of these have already been stated and discussed. Others include developmental considerations, e.g., emotional, psychological, physical, and intellectual. Process-oriented science invites students to manipulate objects and can, therefore, increase enthusiasm for science. It gives students an opportunity to be successful and provides a more variegated approach to learning science than does a mere reliance on reading, lectures, and discussion. However, if process skill development stops with manipulating equipment and materials, **developmental growth is stunted.**

In using process skills, students are first exposed to simple exploratory activities that become more complex as the student develops and learns more. At the end of secondary school, the student should be able to develop solutions and problem-solving strategies for non-complex problems, both in the classroom or out. **It is important to state that the problem-solving domain of science is as valued as the content domain.** Classroom teaching must reflect that value.

Basic Processes

A WORKING LIST OF KEY PROCESS SKILLS

OBSERVING

This is the most basic skill of science. Observing is using the senses to obtain information about objects and events. This skill includes using scientific equipment and instruments for extending the range of human senses, as well as the ability to distinguish relevant from non-relevant observations.

INFERRING

An inference is a tentative explanation that is based on one or more observations. Available data are gathered (observed) and a judgment is made. Such judgments are never absolute. They only reflect what seems to be the most probable judgment. Clearly, they are subject to change as new information is accumulated.

CLASSIFYING

A process for imposing order on collections of objects or events. Classification systems are used to identify objects or events, to show similarities, differences, and interrelationships. The test for a good classification system is whether someone else can use it. It is an important tenet of science that all classification systems are arbitrary and may change as criteria changes.

MEASURING

A procedure by which one uses an instrument to estimate a quantitative value associated with some characteristic of an object or an event. It requires the ability to use instruments properly and the ability to carry out calculations with the measurements made. Measuring assumes that one is familiar with using number systems to express ideas, observations, relationships–often as complements to words.

USING SCIENTIFIC/MATHEMATICAL SYMBOLS

These include the symbolic language of science and mathematics: graphs, tables, and charts, and using scientific symbols and conventions.

USING TIME/SPACE RELATIONSHIPS

These relationships are often among the most difficult for young people to master, because although many events take place quite quickly, others are imperceptibly slow. Developmentally, children often equate slow movement with no movement. Hence stars are fixed in the firmament and somehow night and day just happen. Time/space mastery is often taken for granted in young children; textbooks often blandly discuss difficult concepts such as orbital movements, and geological timelines that have little meaning to students who do not have a clear idea or concept of how long a year is, much less millions of them.

INTEGRATED PROCESSES

INTERPRETING DATA

Data are the pieces of information collected to answer questions. Interpreting data is concerned with using data to make inferences, predictions, and to draw hypotheses. It is also concerned with developing skills in making statistical statements about collections of data, e.g., mode, mean, median, range, and average deviation. Perhaps most importantly, skills in data interpretation allow one to estimate how closely reality has been approximated, that is, how large the error is.

PREDICTING

Predicting is the ability to make a specific forecast of what a future observation will be. This is a very important skill and it relies on the mastery of observation, inference, and classification skills. Predicting is not a series of random guesses. Although many predictions are wrong because one does not have accurate information, they are based upon evidence gathered with the skills described above.

COMMUNICATING

Communication is not peculiar to science, but common to all human endeavors. Scientists communicate orally and by written words, diagrams, maps, graphs, computer simulations, and mathematical equations. Communication is essential to science because it is in communicating ideas and results of experiments that knowledge is verified by others.

Hypotheses are always subject to tests. The real scientist will change the hypothesis if tests warrant...

FORMULATING HYPOTHESIS

A hypothesis is a generalization that is based on many observations and inferences. By using a hypothesis, some predictions can be made, even though it may be imperfect. Obviously, the better the hypothesis, the more accurate the predictions.

IDENTIFYING AND CONTROLLING VARIABLES

When solving a problem, one must be able to present it so that others can verify what has been accomplished, and the conclusions drawn must be replicable. In order to do this, all of the factors that may influence the solution must be identified. Temperature, location, time, duration, are all examples of factors that can change and, in changing, can alter the results of a test.

Ideally, before a test can be initiated, scientists attempt to identify all the variables. By changing one variable at a time, they can determine how that variable will affect the outcome. *Science: A Process Approach,* (American Association for the Advancement of Science, 1970) describes this kind of investigation as follows: *Change (manipulate) one variable in a systematic way, and watch for and measure corresponding changes in another (the responding) variable; hold constant (keep the same) all the other variables you can think of while you are manipulating one variable and observing the response of another.*

Models are essential to understand science and technology, but may be difficult for very young children.

SCIENTIFIC MODEL BUILDING

Scientific models provide a possible explanation of how a system functions, although they may not give an absolutely accurate description of what is really happening in that system. To properly use scientific models, the scientist or student must be able to evaluate the factors that contribute to the system of interest. Model building can satisfy the student's need for thinking in concrete terms about a very abstract system, such as an atom. By bringing ideas to an accessible, testable scale, models facilitate understanding and enhance prediction. After they are compared to the "real world," or system of interest, models must often be revised. Models can be most frustrating to the non-scientist because they often stand for many years, become accepted as facts, only to have new information uncovered that changes the long-standing model.

EXPERIMENTING

This process encompasses all of the basic and integrated processes. Experimenting often begins with observations that suggest questions to be answered. It may include a hypothesis to be tested. The succeeding steps in an experiment involve identifying and controlling variables, constructing a test, implementing the test, collecting and interpreting data, and sometimes modifying the hypothesis being tested.

SCIENCE IN THE WORLD

SCIENCE AND SOCIETY (S/T/S)

The effects of science and technology on society are truly pervasive. They even extend from the way our federal taxes are allocated for research and development–in 1983 about 80 percent of the expenditures were in applied research and development; the remaining 20 percent were in basic research.

The relationship between science, technological advances, and the quality of life is disputed territory. It is all too easy to characterize the disputes as being about the impact scientific advances and technology have on our lives. In *Ethics and Problems of Hazardous Waste Management: An Inquiry into Methods and Approaches,* Peter Timmerman, Institute for Environmental Studies, University of Toronto, points out that what makes many of our current dilemmas so difficult is that "the various values systems at odds are rooted in full-scale views of the world which penetrate very deeply into such complexities as people's essential definitions of what constitutes well-being.

Science and society are intertwined, and like Siamese twins, they may be difficult to separate.

'Their clashes are versions of what the philosopher Hegel defined as true tragedy: Not the clash of good vs. evil, but of good vs. good. Things that society produce actually have the potential for damaging the earth and even destroying the society that created them in the first place." (Timmerman, 1984)

This document is being written during a period of perceived educational crisis and it is not surprising, given the fact that we are an advanced scientific and technological society, that considerable attention is focused on the purposes and content of science education. Society, as well as urgent science-related issues, has caused educators to question the content of the current school science curriculum. Should there be any linkage between school science and current concerns, technology, and values? The National Science Teachers Association has taken the position that: "The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enable an individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations.

A common student complaint is, 'Why do we have to take science?" S/T/S ensures that science is related to their daily lives, hence the question is redundant.

The science/technology/society (S/T/S) perspective was also identified as a major new organizer for school science in Project Synthesis, (Harms and Yager 1981), which identifies the ideal state of science education and contrasts it with the actual state of affairs. Project Synthesis identified eight areas of concern within the S/T/S interface. They included energy, population, human engineering, environmental quality, use of natural resources, national defense and space, sociology of science, and the effects of technological development. They recommended, and we still agree, that science education programs should provide students with:

- An understanding of energy problems from a personal perspective
- An understanding of their role in population growth/regulation
- An understanding of the emerging problems in the field of human engineering
- An understanding of the various aspects of environmental quality and those aspects may differ in priority from person to person
- An understanding of the various aspects of using the earth's natural resources
- An understanding of the various accomplishments of space research and national defense programs
- An understanding of the sociology of science
- An understanding of the effects of hard and soft technology on individuals and society
- The background for taking responsible action on energy-related issues confronting society
- The background necessary to understand and react to problems associated with population dynamics
- The background necessary to develop insight into the emerging work field of human engineering and its impact on society
- The background necessary to recognize the variations in acceptable environmental quality in their communities, states and nation, as well as to maintain or improve them and conserve natural resources
- The background necessary to react to the problems and potential benefits to society of the national defense and space programs
- An understanding of the sociological effects of science technology; and,
- An understanding of the impact of technological developments on society, in order to make reasonable and responsible decisions.

ATTITUDE TOWARD SCIENCE

Whatever the career after high school---butcher, baker, candlestickmaker, or grocer, factory/office worker--high school graduates should feel at home with the ideas of science and technology. How do things work? How do I work? What are some of the effects of specific technologies on me and how do I relate to them? What are the scientific principles underlying technology? What are the scientific facts that bear on the issues affecting my life?

Students need the confidence that they can understand the personal dimensions of science and technology and how to use what has been learned in science in everyday life as they make decisions and solve problems. This will help them lead satisfying lives and make informed decisions about their personal well-being. Science is always embedded in moral questions. Therefore, a personally oriented science always asks questions about the human implications of what we have learned.

READING AND WRITING IN THE SCIENCES

As stated previously, too often science is equated with memorizing facts and replicating demonstrations that mimic experiments that occured long ago. We live in an information age and the high school graduate needs to be able to access information from a variety of sources: readers' guides, databases, atlases, and scientific abstracts. Nobody can expect to be an expert, or to be on top of all the research covering any given topic, knowledge is simply growing too quickly. Moreover, knowledge and need for information may be scattered over many disciplines and retrieval skills are needed to extract the information and to evaluate it for validity of claims and biases of sources.

Students need to be able to write a clear, concise account of what they have found. Furthermore, they need to be familiar with word processing technology and the mechanics of preparing reports.

AFFECT

In summary, the purpose of this section is to alert science educators to the current status of this domain in science education–unclear, chaotic, and confused. Given this state of affairs, what should science teachers do?

First of all, science educators have some things going for them. Science can engage students. There is much in science that is fun, of absorbing interest, and of surpassing importance in the modern world of the student. Because of the way science is constructed, students are offered many opportunities to be successful.

Do scientists really possess the affective characteristics such as objectivity, open-mindedness, skepticism, and detachment ascribed to them? The evidence from several studies is that they do not. All that we know points out the humanness of scientists; they share our prejudices and foibles. They can be secretive in their race for discovery and fame, and there are many fascinating tales of both heroics and infighting, selflessness, and yes, even occasional cheating.

One thing that educators can do is present more accurate pictures of scientists. These characteristics, intertwined as they are in scientists (as well as in all of us), are suitable for students' examination and evaluation. They will learn that it is not easy to separate "good" from "bad."

Chapter 3

Science

Education

Concept Level Learner Outcomes

Essential Learner Outcomes

CHAPTER 3

INTRODUCTION

In the previous chapter, key or basic concepts and the overarching ideas of science, were presented. A case was made that teaching to an understanding of **overarching concepts** was the only alternative to the burgeoning body of facts and discoveries that we call science.

One of the three basic elements of outcome-based education (OBE) is learner outcomes. Model learner outcome documents published by the Minnesota Department of Education list these outcomes in a hierarchy, from the broadest, most general learner goals as listed in Chapter 1, to the program level learner outcomes referred to in Chapter 2 to the more specific concept level learner outcomes offered as models in this chapter.

Each concept outcome in this document is there because a committee of teachers and science educators felt they were examples of the best research and practices. The committee felt these outcomes were important for all students to know, not because they had intrinsic value in and of themselves, but that together they would provide a basis for scientific literacy. The committee strongly felt that together the concept outcomes provided enough grist for a literate, problem- solving citizen. It is assumed that all science programs in Minnesota will include as many of the rather broad concept outcomes as possible as they develop their K-12 science program.

Literacy is the aim of K-12 science education. To produce a program that meets that goal it must be describable.

A sample of about one-third of these concept outcomes is underlined. The science committee, the State Curriculum Advisory Committee, and the State Board of Education feels these concepts are:

- central to understanding the subject matter
- of lifelong importance to the learner; and
- representative of the full range of knowledge through integration of cognitive and affect outcomes.

TEACHING TO OBJECTIVES

According to PER legislation, the underlined or essential outcomes must be included when the district develops science learner outcomes on their curriculum review cycle. These essential outcomes are the basis for the newly developed state science assessment that all districts will use in their PER assessment cycle.

Readers are encouraged to review the outcomes, to consider where their subject, level, school, etc., fit. Readers are especially invited to look at this chapter very critically in light of program assessment, sequencing outcomes, and matching outcomes with the student's developmental level.

I. OVERARCHING CONCEPTS

A. CAUSE/EFFECT

As a result of active involvement of science experiences, students will:

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
A. 7 B. 7, 10, 12 C.1, 2, 3, 4, 5,6 D. 2 K. 1	1. identify cause and effect within a system;	**Applying Environmental**	
	2. apply the concept of cause and effect to a scientific investigation;	**Applying**	
	3. cite examples that support the concept that all things in nature are caused, and that nothing happens in nature that is not caused by a natural force;	**Applying, Affective Multicultural, Gender Fair, Environmental**	
	4. describe occurrences in nature in terms of cause and effect relationships;	**Applying, Integrating International Environmental**	
	5. analyze effects as having various causes, and causes as having various effects, depending on the circumstances;	**Integrating**	
	6. evaluate cause and effect relationships that impact daily life;	**Integrating, Affective Multicultural, Gender Fair**	
	7. cite specific examples indicating they understand that human activity affects the global environment positively and/or negatively;	**Applying, Integrating Multicultural, Gender Fair, Environmental**	
	8. use an if/then relationship to describe cause/effect relationship.	**Applying**	

B. CHANGE

As a result of active involvement of science experiences, students will:

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
A. 7 B. 3, 4, 6, 7, 8, 12 C. 1, 2, 3, 5 D. 2 K. 1, 2, 3, 6	1. describe change by comparing the final state of a system or organism to its initial state;	**Knowing Environmental**	
	2. cite evidence that life on earth has evolved in response to a changing environment;	**Integrating International Environmental**	
	3. classify various changes as chemical, physical, or nuclear;	**Applying, Integrating**	
	4. identify and predict changes of state;	**Applying, Integrating**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	B. CHANGE (cont'd.) **As a result of active involvement of science experiences, students will:**		
	5. understand that science teaches all changes are explainable by natural law;	**Integrating International**	
	6. recognize and control factors that influence the rate and magnitude of change.	**Knowing**	
	C. CYCLES **As a result of active involvement of science experiences, students will:**		
A. 6, 7 B. 6, 7, 12, 13 C. 1, 2, 3, 5 I. 3 K. 6	1. recognize patterns where certain events or conditions seem to be repeated at regular intervals or periods;	**Applying, Multicultural, Gender Fair Affective, Environmental**	
	2. use the concept of cycles to predict events;	**Applying International Environmental**	
	3. recognize that in the natural environment, cycles work together as a dynamic, integrated, and interacting whole;	**Integrating International Environmental**	
	4. understand the concept of ecological succession;	**Integrating International Environmental**	
	5. describe energy transfer within a living system;	**Knowing, Applying**	
	6. calculate the total energy from the sum of potential energy and the kinetic energy.	**Knowing**	
	D. ENERGY/MATTER **As a result of active involvement of science experiences, students will:**		
A. 6, 7 B. 1 C. 1, 3, 4, 5 K. 6	1. understand that energy and matter are related;	**Knowing**	
	2. describe the nature of energy transformation within a given biotic or abiotic system;	**Knowing, Applying Environmental**	
	3. describe applications of electromagnetic radiation;	**Applying, Knowing**	
	4. define energy as the ability to do work;	**Knowing**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	D. ENERGY/MATTER (cont'd.) **As a result of active involvement of science experiences, students will:**		
	5. define matter as that which composes all things;	**Knowing**	
	6. analyze and describe motion as a rate of change of position;	**Integrating**	
	7. understand the interrelationships between potential and kinetic energy;	**Applying**	
	8. describe how energy is transferred;	**Knowing**	
	9. describe the effects of energy on the motion of microscopic particles of matter.	**Knowing**	
	E. EQUILIBRIUM AND HOMEOSTASIS **As a result of active involvement of science experiences, students will:**		
A. 6, 7 B. 6, 13 C. 1, 3, 5 I. 3	1. identify how biotic and abiotic systems establish and maintain equilibrium;	**Applying**	
	2. predict effects of external forces on a system at equilibrium;	**Applying, Integrating**	
	3. cite examples of homeostasis in a living organism;	**Knowing**	
	4. describe predator/prey relationships in populations;	**Applying, Integrating** **Environmental**	
	5. define population in terms of time, place, species, and density;	**Knowing** **Environmental**	
	6. explain that in a closed system, a balance among forces is a condition for equilibrium;	**Knowing, Applying** **Environmental**	
	7. recognize a system in equilibrium.	**Integrating** **Environmental**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	F. INTERACTION **As a result of active involvement of science experiences, students will:**		
A. 6, 7 B. 6, 7, 10 C. 1, 2, 3, 4, 5 D. 2	1. cite examples where two or more things influence or affect one another;	**Knowing, Applying** **Environmental**	
	2. give specific examples of major relationships between species in a community, such as predation, parasitism, and/or symbiosis;	**Applying** **Environmental**	
	3. give examples of populations, communities, and ecosystems;	**Applying** **Environmental**	
	4. identify factors that affect the rate of a chemical reaction;	**Knowing**	
	5. explain interrelationships between the ocean, atmosphere, and land, to produce large-scale weather changes;	**Integrating** **Environmental**	
	6. describe and apply the law of universal gravitation.	**Applying**	
	G. FUNDAMENTAL ENTITIES **As a result of active involvement of science experiences, students will:**		
A. 6, 7 B. 1, 3, 4, 13 C. 1, 2, 3, 4, 5 I. 3 K. 3, 6	1. identify the fundamental units of given biotic or abiotic systems;	**Knowing** **Environmental**	
	2. explain operations of a system in terms of its fundamental entities;	**Integrating** **Environmental**	
	3. explain basic life functions in terms of cell interactions;	**Applying, Integrating**	
	4. describe a substance in terms of atoms and molecules;	**Applying, Integrating**	
	5. explain macroscopic phenomena such as diffusion phase changes in terms of fundamental particle interactions;	**Integrating**	
	6. distinguish between fundamental entities, e.g., mass and derived entities, e.g., weight;	**Applying, Integrating**	
	7. cite evidence that matter is made up of particles;	**Integrating**	
	8. describe the basic forces of nature (gravity, electromagnetic, strong, weak).	**Applying**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	H. PROBABILITY **As a result of active involvement of science experiences, students will:**		
A. 6, 7 B. 1, 2, 3, 4 C. 1, 2, 3, 4, 5 K. 6	1. identify uses of probability to predict occurrences in nature;	**Knowing, Applying** **Environmental**	
	2. cite examples that probability cannot determine or describe the occurrence of a specific event;	**Integrating**	
	3. calculate the relative frequency with which an event occurs in an indefinitely large number of trials;	**Knowing, Applying**	
	4. evaluate the relative probability of earthquake occurrences;	**Integrating**	
	5. describe or predict a plant community given abiotic factors such as temperature, rainfall, altitude, etc.;	**Integrating** **Environmental**	
	6. explain why one can predict certain experimental regularities on the half-life of a sample, containing a very large number of radioactive nuclei.	**Applying, Integrating**	
	I. PATTERNS AND SYMMETRY **As a result of active involvement of science experiences, students will:**		
A. 5, 6, 7 B. 6, 7, 12 C. 1, 2, 4, 5 I. 3	1. recognize patterns in nature;	**Knowing, Applying** **Environmental**	
	2. identify various forms of symmetry in nature;	**Knowing**	
	3. cite evidence that most events in nature follow patterns;	**Integrating** **Environmental**	
	4. demonstrate how an organisms' symmetry becomes more and more similar as one moves from kingdom to species;	**Integrating**	
	5. analyze repeating cloud groups for patterns of atmospheric circulation;	**Integrating**	
	6. describe the organizational pattern of multicellular organisms;	**Applying**	
	7. describe isomerism in organic compounds in terms of molecular symmetry;	**Applying**	
	8. identify and predict properties that occur in a periodic system;	**Applying**	
	9. describe the image formation of mirrors and lenses.	**Applying**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	J. SYSTEMS **As a result of active involvement of science experiences, students will:**		
A. 5, 6, 7 B. 6, 7, 12, 13 C. 1, 2, 3, 5 I. 3	1. describe a system in terms of its interacting parts or subsystems;	**Appying, Knowing** **Environmental**	
	2. describe how a series of interacting parts or subsystems can be combined to form a system;	**Knowing, Applying** **Environmental**	
	3. demonstrate that a system is a group of interacting components;	**Integrating** **Environmental**	
	4. relate a system to natural events and concepts such as cycles and weather;	**Integrating** **Environmental**	
	5. analyze levels of organization in astronomical systems: solar system, galaxy;	**Integrating**	
	6. contrast air circulation in high and low pressure systems;	**Integrating**	
	7. describe a system in terms of its being open or closed;	**Applying** **Environmental**	
	8. use an understanding of the total system when solving problems.	**Integrating** **Environmental**	

II. PROCESS SKILLS–BASIC AND INTEGRATED

Basic

A. OBSERVING

As a result of active involvement of science experiences, students will:

A. 6 B. 6, 7 C. 1, 3, 5	1. employ all the senses to collect information concerning objects, systems, and events;	Applying Psychomotor	
	2. distinguish observations from inferences;	Applying Environmental	
	3. use specific tools in an appropriate manner which extends the senses (e.g., microscope, hand lens, stethoscope, thermometer) to make observations;	Integrating Psychomotor Information Technology	
	4. list several observations of a real object, system, or event;	Applying	
	5. describe an organism in terms of its observable characteristics.	Applying	

B. INFERRING

As a result of active involvement of science experiences, students will:

A. 6 B. 6, 7 C. 1, 3, 5	1. examine observations and select the most likely explanation;	Applying, Integrating Environmental	
	2. realize that inferences based on observations are tentative and subject to change with new data;	Integrating Environmental	
	3. use a cross section of a tree trunk to infer growing conditions over the tree's life;	Applying Environmental	
	4. infer the environmental forces that have had the greatest effect on the evolution of landforms;	Integrating Environmental	
	5. describe a logical ancient ecosystem after looking at a fossil deposit;	Integrating Environmental	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	B. INFERRING (cont'd.) **As a result of active involvement of science experiences, students will:**		
	6. describe specific terrains on topographic maps and relate map details to their actual physical dimensions;	**Applying**	
	7. make reasonable inferences concerning the characteristics of an object, system, and/or event;	**Applying**	
	8. infer probable reactants from the products of a chemical reaction;	**Applying**	
	9. infer an animals' behavior after observing its tracks;	**Applying**	
	10. determine the charge of an object based on its interaction with other charged objects.	**Integrating**	
	C. CLASSIFYING **As a result of active involvement of science experiences, students will:**		
A. 6 B. 6, 7 C. 1, 3, 5	1. impose order on collections of objects or events based on physical or chemical properites;	**Applying** **Psychomotor**	
	2. develop schemes to differentiate specific objects, systems, or events from a collection using valid criteria;	**Applying, Integrating** **Psychomotor**	
	3. develop classification systems that can be used by other people to reliably get the same result;	**Applying** **Psychomotor** **Environmental**	
	4. understand that classification systems are arbitrary and may change with different classification criteria;	**Integrating** **Environmental**	
	5. design a key to classify a set of objects;	**Applying**	
	6. separate a collection into sets and subsets;	**Applying**	
	7. use binomial classification systems.	**Applying**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	D. MEASURING **As a result of active involvement of science experiences, students will:**		
A. 5, 6, 7 C. 1, 5 K. 6	1. use a variety of conventional and international units to quantify scientific phenomena and/or events;	**Applying** **Psychomotor** **International**	
	2. use common tools of science to measure objects and events; such as computer probeware, balance, thermometer, meterstick, timepiece, graduated cylinder;	**Applying** **Psychomotor** **Information Technology**	
	3. average several measurements to reduce error;	**Applying**	
	4. estimate the size and/or magnitude of objects or events;	**Applying, Integrating** **Environmental**	
	5. know that each method of measurement has inherent error;	**Applying** **Environmental**	
	6. measure out quantities of a specific amount;	**Applying**	
	7. estimate large numbers such as a population of yeast or bacteria;	**Applying**	
	8. use a geologic table to estimate the age of fossils;	**Applying**	
	9. determine the size of the field of view of the microscope in a different magnification;	**Applying, Integrating**	
	10. read a thermometer to two significant figures.	**Applying, Integrating**	
	E. USING SCIENTIFIC, MATHEMATICAL SYMBOLS **As a result of active involvement of science experiences, students will:**		
A. 5, 6, 7	1. be able to construct, read, and interpret information in symbolic form (graphs, tables, and charts) using scientific symbols and conventions;	**Integrating** **Environmental**	
	2. manipulate mathematical formulas and expressions to solve problems;	**Applying, Integrating**	
	3. collect, organize, and display data to compare two events or phenomena;	**Integrating**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	E. USING SCIENTIFIC, MATHEMATICAL SYMBOLS (cont'd.)		
	As a result of active involvement of science experiences, students will:		
	4. know and use common symbols of science;	**Applying**	
	5. use symbols to represent specific genotypes in genetic problems;	**Applying**	
	6. use letter symbols to represent chemical elements;	**Knowing**	
	7. use scientific notation.	**Applying**	
	F. USING TIME/SPACE RELATIONSHIPS		
	As a result of active involvement of science experiences, students will:		
A. 4, 5, 6, 7 B. 6, 7 C. 1, 2, 3, 5 K. 2, 6	1. describe events over time, such as seeds growing or eggs hatching;	**Integrating**	
	2. describe a population's response to environmental changes;	**Integrating** **Environmental**	
	3. describe the location of an object in reference to another object or frame of reference;	**Integrating**	
	4. place events in serial order;	**Applying**	
	5. solve relative position and motion problems;	**Applying**	
	6. describe the implications of traveling near the speed of light.	**Integrating**	

INTEGRATED

G. INTERPRETING DATA

As a result of active involvement of science experiences, students will:

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
A. 5, 6, 7 B. 10 C. 1, 2, 3, 5 F. 3 K. 2, 6	1. identify patterns or regularities in a set of data;	Applying Environmental	
	2. determine which data are significant to a laboratory investigation;	Integrating	
	3. distinguish qualitative data (information) from quantitative data;	Applying, Knowing	
	4. use experimental data to establish mathematical relationships among variables;	Integrating	
	5. draw conclusions from data displayed on a variety of graphs and charts;	Integrating Environmental	
	6. make statistical statements about collections of data such as mode, mean, median, range, and average deviation.	Applying	

H. PREDICTING

As a result of active involvement of science experiences, students will:

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
A. 4, 5, 6, 7 B. 6, 7 C. 1, 2, 3, 5 K. 1, 2, 6	1. make predictions from a graph;	Applying	
	2. from a sequence of events, predict the next logical step and defend the answer;	Applying, Integrating Environmental	
	3. change a prediction in light of new information;	Integrating	
	4. predict changes in the weather based atmospheric data;	Applying, Integrating	
	5. make simple predictions about electrical circuits;	Applying, Integrating	
	6. make predictions concerning a substance based on its place on a periodic table;	Applying	
	7. predict the genotypes and ratios of the offspring expected from a given genetic cross.	Applying	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	I. COMMUNICATING **As a result of active involvement of science experiences, students will:**		
A. 2, 3, 4, 5, 6, 7 B. 6, 7, 10 C. 1, 2, 3, 5 E. 1 H. 3 K. 6 L. 2 M. 1	1. organize information and data in such a way that others can understand it;	**Applying**	
	2. describe an event or procedure using appropriate scientific terms;	**Integrating** **Environmental**	
	3. use a variety of methods to communicate collected data such as computer programs, graphs, tables, and charts;	**Integrating** **Information Technology**	
	4. demonstrate the ability to follow written and or oral directions;	**Applying**	
	5. describe an experimental process and procedure so it can be replicated by others;	**Applying, Integrating**	
	6. set up a demonstration to illustrate an event or phenomenon;	**Applying**	
	7. make an oral presentation of the results of an investigation.	**Applying, Integrating**	
	J. FORMULATING HYPOTHESES **As a result of active involvement of science experiences, students will:**		
A. 5, 6, 7 B. 6, 7, 10 C. 1, 2, 3, K. 6	1. generate tentative relationships that are subject to testing;	**Applying, Integrating**	
	2. understand that any hypothesis is subject to a fair test;	**Knowing, Applying** **Psychomotor**	
	3. generate a hypothesis for phenomena (such as the circular patterns of mushrooms often seen on lawns);	**Applying, Knowing**	
	4. generalize why the radiation count is inversely related to the distance from a source.	**Knowing, Applying**	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	K. IDENTIFYING AND CONTROLLING VARIABLES **As a result of active involvement of science experiences, students will:**		
A. 5, 6, 7 B. 1, 2, 3 K. 6	1. recognize that a variable is a condition that may influence the outcome of an investigation;	Knowing, Applying Psychomotor Environmental	
	2. identify and control variables that may influence an outcome or reaction;	Knowing, Applying Environmental	
	3. classify a variable as controlled, manipulated, and responding;	Integrating Environmental	
	4. know the importance of manipulating one variable at a time;	Applying Psychomotor	
	5. manipulate the rate of a chemical reaction by changing either the temperature, the concentration, or a catalyst;	Applying, Knowing Psychomotor	
	6. demonstrate that variables can be isolated.	Applying	
	L. SCIENTIFIC MODEL BUILDING AND USE **As a result of active involvement of science experiences, students will:**		
B. 6, 7 C. 1, 2, 3, 5 K. 6	1. cite and employ models from a variety of scientific disciplines;	Knowing	
	2. compare and contrast scientific models as: analog, scale, and symbolic;	Integrating Psychomotor	
	3. site how models are created to explain and predict natural phenomena;	Integrating Environmental	
	4. describe how scientific models are subject to change;	Applying Environmental	
	5. critically examine a model and identify its limitations;	Knowing, Applying Environmental	
	6. construct a model that explains a phenomenon;	Knowing, Applying Environmental	
	7. explain how traits can be passed from one generation to another using the gene theory;	Knowing, Applying	

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
	L. SCIENTIFIC MODEL BUILDING AND USE (cont'd.) **As a result of active involvement of science experiences, students will:**		
	8. determine the configuration of geographic features on topographic maps;	Integrating International	
	9. recognize various models of the atom and give reasons for using each model.	Applying	
	M. EXPERIMENTING **As a result of active involvement of science experiences, students will:**		
A. 4, 5, 6, 7 C. 1, 2, 3, 5 K. 1, 2, 6	1. employ scientific process skills to solve an open-ended problem;	Integrating Environmental Information Technology	
	2. design a fair test for a hypothesis;	Integrating Psychomotor Environmental	
	3. respect and adhere to safe laboratory procedures when conducting an experiment;	Integrating Psychomotor	
	4. design a controlled experiment.	Integrating Environmental	

III. PERSONAL NEEDS

ATTITUDE TOWARD SCIENCE

As a result of active involvement of science experiences, students will:

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
B. 3 C. 1, 2, 3, 4 E. 1, 4, 6 F. 1, 3 G. 3 H. 2, 3, 4 D. 2	1. distinguish a scientific way of knowing from non-scientific ways of knowing;	Integrating Environmental	
	2. recognize and cite examples of the important contributions in science of culturally diverse men and women;	Knowing, Affective Multicultural, Gender Fair, Youth Services Career and Work Readiness	
	3. act on the belief that science and access to science-related careers is not restricted by gender, cultural diversity, or handicap and disability;	Knowing, Applying Integrating Multicultural, Gender Fair, Career and Work Readiness, Disability Awareness	
	4. describe what scientists do;	Knowing	
	5. demonstrate an increased appreciation of the world around them;	Affective	
	6. exhibit a sense of wonder, curiosity, and longing to know;	Affective, Integrating	
	7. give examples of how science impacts their daily lives;	Integrating, Affective Multicultural	
	8. use science process skills to solve everyday problems;	Gender Fair International, Family Life and Parenting	
	9. demonstrate that they read about science and technology in the public media, periodicals, newspapers, etc.;	Affective Multicultural, Gender Fair	
	10. demonstrate an avocational interest in science through volunteerism, or other forms of personal endeavor.	Affective Multicultural, Gender Fair, Youth Services	

IV. SCIENCE IN THE WORLD

SCIENCE/TECHNOLOGY/ SOCIETY (S/T/S)

As a result of active involvement of science experiences, students will:

STATE BOARD OF EDUCATION GOALS	SCIENCE LEARNER OUTCOMES	DEVELOPMENT AND CONCEPT EMPHASIS	TEST ITEM BANK
A. 5, 6, 7 B. 2, 5, 6, 7, 9, 10, 11 C. 1, 2, 3, 4 D. 2, 4 E. 4 F. 3 G. 3 I. 4 J. 2 K. 5 L. 2 M. 1, 2, 3	1. discuss the effect of the human species on biotic and abiotic environments;	**Integrating Environmental**	
	2. demonstrate through actions that they accept their role as responsible citizens of the environment;	**Integrating, Gender Fair, Affective International Environmental, Youth Service**	
	3. recognize and cite examples of the tradeoffs implicit in the resolution of an S/T/S issue;	**Applying, Integrating International Affective Environmental**	
	4. give examples and explain the dynamic interplay between science and society;	**Integrating International Affective Environmental**	
	5. recognize scientists as people with personal and human characteristics;	**Multicultural, Gender Fair, Affective, Integrating**	
	6. recognize that there is a relationship between science and economics;	**International Integrating Environmental**	
	7. have an understanding of various points of view about environmental quality;	**Multicultural, Gender Fair, Affective International Environmental**	
	8. relate the things learned in science to their personal experiences;	**Integrating, Applying Family Life and Parenting**	
	9. discuss how technology affects science and society, as well as impacts family life.	**Applying, Integrating International, Affective, Family, Environmental**	

V. READING AND WRITING IN THE SCIENCES

As a result of active involvement in science experiences, students will:

	1. demonstrate skills that allow them to access information through various media sources such as reference books and textbooks, reader's guides, databases, maps, atlases, and scientific abstracts to locate and obtain information on a given topic;	Applying, Media Information Technology	
A 1, 2, 3, 6, 7 B. 1, 10 C. 1, 2, 3, 4	2. analyze and evaluate sources of information, validity of claims, and biases of sources;	Integrating, Affective Media, Environmental	
	3. produce a concise, accurate, and logical summary of an investigation which they have performed;	Integrating	
	4. write a clear account of an experiment they have performed;	Integrating	
	5. summarize scientific findings in a written report.	Integrating	

Chapter 4

Science

Education

Transposing Outcomes into the Curriculum

CHAPTER 4

INTRODUCTION

The primary purpose of this document is to provide curriculum planners with: 1) models of learner outcomes which they **may** choose to incorporate into the district science curriculum; and, 2) science essential learner outcomes that are **required** and will be assessed as part of each district's PER review cycle.

Chapter 2 provides districts and curriculum planners with a rationale for science education. Chapter 3 provides the concept outcomes, as well as those considered to be essential.

Chapter 4 provides practitioners with the insight and skills to take the process of learner outcome development, in all of its stages, from the most general to the most specific, and align the outcomes with the other two major components of outcome based education (OBE), instruction and assessment.

This chapter is divided into two major sections. The first section provides a bridge between the rationale for science education developed in Chapter 2 into the basis for curriculum centered around the learner outcomes found in Chapter 3. It also describes instructional practices advocated by science educators.

A basic tenet of science education is that it is accessible by students of all races, genders, and economic backgrounds.

The second section contains questionnaires to assess the condition and determine the relative strengths and weaknesses of the science program. The principle objectives are to examine the science scope and sequence to determine what outcomes are taught at each level of schooling and the inclusiveness of the science program, e.g., multicultural, gender fair, disability aware, and gifted and talented.

It is hoped that through the process of self-assessment, elementary, middle, and senior high school teachers will increase their understanding of one another, their tasks, and objectives, and develop a sense that "we are in this together." Clearly, when cooperation and an increase in empathy occur, the result will be better and more consistent instruction for children. Not all questionnaires may be pertinent to your needs. Feel free to discard/modify those that are not.

During the self-assessment of the science program, information is collected individually and is summarized at the end of the process. Careful attention to the summary, as well as the patterns emerging from each self-assessment questionnaire, should provide insight into which levels of the K-12 spectrum are most appropriate for which learner outcome, as well as provide a summary scope and sequence, a kind of curriculum-at-a-glance. Finally, the questionnaires allow curriculum planners to objectively ascertain missing components, components that are needed if all of the essential learner outcomes are to be implemented.

It is suggested that curriculum planners read *Model Learner Outcomes for Science Education* carefully as their first step. Afterwards, using the material found in the appendices or other assessment tools, a self-assessment of the science program should be made. Planners are encouraged to implement the teaching strategies, evaluation techniques, and translation procedures outlined in the pages that follow once the self-assessment process has been completed.

All students can learn; an exemplary program reflects that value.

At the heart of OBE is the belief that all students can learn. Based on this belief, it is critical that the sequencing and placement of the outcomes is based upon the developmental stages of students.

Alignment of learner outcomes, **appropriate** assessment techniques, instructional strategies, as well as the commitment to assess what is valued, are critical to ensuring student achievement within an OBE framework. Once it is known what is necessary for students to learn, and techniques are developed for evaluating their progress, important decisions need to be made about how to assist students in achieving learner outcomes. This chapter offers some suggestions concerning:

1. Children's developmental stages: how to select concepts and teaching/learning techniques that are developmentally appropriate;

2. How science ought to be taught and learned;

3. Using results of program assessment to evaluate what is already taught, what is needed, and what can be discarded; and

4. The development of constructivist curriculum that is based on essential concepts, processes, and personal needs reflected in the learner outcomes and the State Board goals.

SCIENCE EDUCATION: The Unfolding of Thinking

> *Compared to other living organisms that we know about, humans enter this world quite empty-headed. Many species of birds, fish, and other animals are preprogrammed with information that enables them to survive, gather food, and reproduce their own kind. Some can travel to locations they never experienced directly. Others behave in ways that are independent of learning. But the human baby is quite helpless. It must construct a view of the world itself.*
>
> *Lawrence F. Lowery, Developing Minds*

Students are the primary focus of good curriculum building

How people think and learn to think is not something we often concern ourselves about. Our view is that knowledge is personally constructed and presented to learners in a manner that is developmentally appropriate.

The sequential development of thinking capabilities and the idea that we construct knowledge is supported by a novel and diverse research base. Science educators are probably most familiar with the work of cognitive psychologists, including Jean Piaget, Jerome Bruner, Robert Gagne, and Erik Erickson. Two other cognitive psychologists deserve mention. The research of Joseph Novak and David Ausubel, who, while repudiating the Piagetian notion of stages of cognitive development, also provides convincing evidence that we construct what we come to know.

Piagetian Education

The discussion that follows is based on the work of the Swiss psychologist Jean Piaget. Because it is often referred to in the science education literature, it is important that curriculum planners and developers be aware of Piagetian theory and its implications for science education. The overall goal of Piaget's research was to develop a general theory of knowledge. The approach he took was developmental. How and why does knowledge develop? How do individuals come to know what they know? How does the ability to reason mature over time? Piaget's research was based on naturalistic observations, interviews, and the involvement of children in tasks.

In seeking explanations for the development of cognitive abilities, Piaget identified five major developmental stages of reasoning that are spaced and occur at intervals during a person's life span. These stages are: **sensorimotor**--information is organized into mental structures by sensory experiences; **preoperational**--thinking is centered on self and is often intuitive; **concrete**--meaning is primarily in physical terms; **transitional**--in-between concrete and formal; and **formal**--thoughtful thinking in terms of the possible or hypothetical. These stages can be described simply as the active child, the intuitive student, the practical student, and the reflective student.

While it has been well documented that children move through these stages in the same order (including across cultures), it is important to understand that the rate varies between individuals, and that the developmental stages are not strictly age dependent.

While it is clear that children pass through stages of intellectual development, they do so at differing rates.

Each stage represents both new thinking capabilities and also a new period for integration and consolidation of cognitive content. In each stage, experience, information, and knowledge are uniquely organized into a different view of the world. In the sensorimotor period, it is a highly sensory world view; in the period of formal thought, it is the ability to identify and isolate the possible combinations of variables (and establish their relationships) involved in complex problems.

Characteristics of each of the four Piagetian stages are summarized in Figure 4.1. The structure of the table may suggest that the characteristics are mechanical or benchmarks. However, they should be viewed as parts of a developmental gradient that all people move along, although not at the same pace. In the sensorimotor period, for example, the child begins with no concept of space and ends up with a concept of immediate space. Furthermore, the development of reasoning is both richer and a more differentiated process than is shown here. Interested readers should refer to the literature.

FIGURE 4.1. DEVELOPMENTAL STAGES

STAGE	APPROXIMATE AGE RANGE	APPROXIMATE GRADE LEVEL	THINKING CHARACTERISTICS
Sensorimotor	0-2	Preschool	Interacts through sensory and motoric activities. Developing concept of self, space, time, cause/effect, play and object permanence (objects exist even when out of sight). Actions imposed on objects one at a time.
Preoperational (Intuitive student)	2-7	Preschool 2	Intuitive answers ("because"). Egocentric (child center of reality). Aware of past, present, and future. Make believe play. Animistic explanations of cause/ effect. Reasons in one direction: A causes B, B causes A. Groups two objects (attributes). Links two events (relationship). Can imitate actions.
Concrete Operational (Practical student)	7-11	3-6	Restricted to direct experiences (requires objects). Classifying/ grouping with a rational logic. Reversing through processes (A B, B A). Mathematical operations--combine more than one idea at a time. Unaware of inconsistencies and mistakes in reasoning. Requires clear, sequential directions for projects.
In Transition (In-between student)	11-15	Middle/High School	Rational, but unsystematic approach to problem solving. Uses concrete procedures to solve abstract problems. Inadequate observations and procedures used for difficult problems.
Formal Operations (Reflective student)	14-Adult	Senior High	Abstract reasoning. Hypothetical-deductive reasoning (can manipulate and control variables). Proportional reasoning. Combinatorial reasoning (organize and reorganize).

SCIENCE AND THE GIFTED AND TALENTED LEARNER

The State Board of Education adopted a rule which provides for the education of gifted and talented (G/T) students. The rule states that "The Educational Program shall provide a general education for all pupils and suitable special education for exceptional children–handicapped, gifted, and talented." (3500.0500, Subpart 1)

The definition of giftedness adopted by the Minnesota State Board of Education in 1976 states: Gifted and talented children are those who by virtue of outstanding abilities are capable of high performance. These are children whose potentialities can be realized through differentiated educational programs and/or services beyond those normally provided by the regular school program. Children capable of high performance include those with demonstrated achievement or potential ability in any of the following areas, singly or in combination: general intellectual ability, specific academic aptitude, creative or productive thinking, leadership ability, visual and performing arts.

Because G/T students may not be identified as such it is important to become familiar with some G/T characteristics. The following list of G/T characteristics to be looked for in science class is adapted from several sources although it relies heavily on Trowbridge et al. (1981) and Van Tassel-Baska (1988).

- Has a passion for science–the rage to know.
- Enjoys scientific problem solving and solves such problems both logically and often uniquely.
- Grasps concepts quickly as well as thoroughly.
- Is a "question box"–wants to know things about science.
- Voluntarily reads about science.
- Tendency to make quantitative observations; observations show attention to detail.
- Demonstrates creativity in thinking about scientific problems; designing experiments to solve them; and inventing/designing equipment for scientific work.
- Exhibits advanced development, for example, use and understanding of cognitive concepts, science processses, aesthetic criteria, and ethical issues.
- Is curious.
- May exhibit boredom and frustration with pace of class.

If you think you have a G/T student, talk with the school counselor and/or the G/T coordinator not only for a more objective assessment, but also to help you develop and find appropriate activities. Brandwein (1955) provides an important insight on the identification issue, especially at the elementary level. He prefers the term "science prone" rather than "gifted in science," noting student achievement rather than their aptitude. It is critical that this tendency be encouraged if we are to help students excel as well as to make informed choices.

Trowbridge et al. note that the teacher's question is always, "What can I do to help students achieve their potential in my science class?" Some suggestions for helping G/T students include:

- Mentorship programs with scientists.
- Participation in special projects, e.g., science fairs, independent study, laboratory and field investigations.
- Provision of extensive inquiry-related education experiences which include problem solving, decision making, values clarification (moral and ethical issues in science), the nature of scientific inquiry, general inquiry processes, and science process skills.
- Identify summer programs such as institutes and work opportunities.
- Explore Minnesota enrollment option programs.
- Develop minicourses.

- Individualize a program based on interests and needs.
- Use assessment instruments to measure and diagnose progress in developing those inquiry competencies appropriate for the individual.
- Provide information to students on programs promoting academic excellence, e.g., Minnesota Science Challenge, Inventors Fair.
- Provide a curriculum rich in current technological advances.
- Provide experiences that help students learn more about the activities, beliefs, and characteristics of scientists.
- Use discrepant events in lessons and learning activities.
- Provide independent laboratory work that is more truly experimental. It should include extensive reading, and library use, including computer networks and databases.
- Emphasize the major ideas or concepts within the sciences, rather than step-by-step procedures.
- Provide for the needs of females:

  --Use adult females to provide real-life models, e.g., Minnesota's Project Link.
  --Encouragment to take four years of science and math. Use special discussion groups and films to focus and promote discussion.
  --Make biographies of women scientists available.
  --Emphasize real-life applications of science.
  --Allow sufficient time for solution finding and emphasize diverse problem-solving methods.
  --Relate the changing roles of men and women to the potential for a rewarding career in science.
  --Include materials on the effects of gender stereotyping and bias in science.
  --Select materials that avoid gender stereotypes.
  --Provide information about the activities of women in science, e.g., professional organizations, work, issues.

Model Learner Outcomes for Gifted and Talented Learners contains 30 learner outcomes for science. Five representative learner outcomes from that document are listed below. The student who exhibits or is capable of exhibiting outstanding performance in science will:

- Understand science concepts and processes at an earlier age than the regular curriculum sequence suggests.
- Create new ways of classifying and measuring objects and events.
- Demonstrate ability to make logical, verifiable explanations for something observed or inferred.
- Define, identify, manipulate variables, understand that variables influence the outcome of an investigation.
- Develop an intellectual and career interest in science and technology.

FACILITATING COGNITIVE DEVELOPMENT

Specific suggestions for science instruction, based on Piaget's theory, were first developed by Robert Karplus and his colleagues at the Lawrence Hall of Science, University of California, Berkeley, in the 1960s. This application of Piaget's ideas for science educators is known as the teaching/learning cycle. This design was incorporated into the elementary school science materials developed for the Science Curriculum Improvement Study (SCIS). The teaching/learning scheme is divided into three stages: **Concept Exploration, Concept Explanation, and Concept Extension.** Originally, Karplus referred to these stages as: exploration, invention, and discovery, respectively.

CONCEPT EXPLORATION: The initial stage of the Learning Cycle looks a bit like play. Students are given minimal directions concerning what to look for in a collection of materials. They can work alone or in cooperative groups. Either way they are encouraged to discuss what they observe and to ask questions. While the concept exploration phase appears to be nonstructured, it is strongly controlled by an initial challenge and the materials provided.

For instance, in introducing a unit on sound, students would be provided with a variety of materials: plastic tubes of different lengths and caps to cover the tube ends. Students would be asked: "Can you make sounds using these materials?" "How many ways?" At the high school level, an activity might be a laboratory experiment structured somewhat differently from the traditional, or a field trip that produces observable data. However, these are not the only possibilities for exploration experiences. Videos, films, discussions, demonstrations, thought puzzles, etc., can be used just as effectively at the secondary level.

The most common teaching strategy is built on a lecture-read-laboratory-review-test model. To be effective, the lab ought to come first.

The criterion for an exploration activity is that students are actively engaged at an appropriate level of puzzlement. Piaget referred to the latter as disequilibration. Characteristic student behaviors during an exploration are participation, openness, and active engagement. The exploration activity is open, but directed by an initial challenge. As students use the challenge to interact with the materials, they may observe patterns, identify relationships and variables, and form hypotheses.

The Laboratory: The laboratory plays a central role during the concept exploration phase. Hands-on science has long been recognized as the principal means of teaching complex concepts. Piagetian theory holds that students tend to approach new ideas, especially puzzles, from a trial/error perspective. As students are able to explore a phenomenon or concept, they soon begin to see how things fit together. Scientists call those patterns regularities. Once the patterns are perceived, then and only then can a student make predictions, answering the question: "What would happen if...?"

Figure 4.2 illustrates five types of laboratory investigations. They are arranged in a hierarchy, from limited (no problem solving skills needed) to open (higher order thinking skills required). Ideally, teachers should attempt to ensure that students experience as many of these approaches as possible.

FIGURE 4.2

THE LABORATORY

ACTIVITY	DESCRIPTION
Type I	Does not require formal reasoning. Teaches important skills such as measurement and observation, or how to use laboratory and scientific equipment.
Type II	In these investigations, the student formulates the problem, methods of data collection, makes interpretations, and draws conclusions. This is a true research project and can be an extension of a class discussion or an idea a student wants to pursue based on the student's own experience. It is sometimes difficult for a student to limit the problem to one she or he can handle. Students must be both knowledgeable and have process skills; teachers must be resource persons, facilitators, and research advisors.
Type III	Students continue to get instruction from you (or written materials), but they do not know what results or conclusions to expect. The experiences are guided and students gain practice in finding relationships in their data. This type of laboratory is typical of the exploration activities described earlier.
Type IV	Students are still presented with a problem, but you let them develop their own methodology for collecting data. An example would be, where on a biology class field trip, asking students to compare the life on two quadrants of land. The laboratories provide experience in data collecting skills such as measuring, identifying, and controlling variables, collecting and recording, and making interpretations.
Type V	In these laboratories, students verify concepts or principles. The problems and procedures are specified. Students can be asked about how they verified principles or concepts and data can be probed, analyzed, and discussed. However, if the majority of your laboratory activities are of this type, students will end up with the distorted view that someone knows the right answer. It is unlikely that science will be seen as a basic enterprise of human beings. It will be regarded as a given.

Adapted from Jerry E. Ivins, The Science Teacher, May 1983.

Stratified, random surveys of junior and senior high teachers indicate that the vast majority of laboratories conducted in the secondary schools fall into groups I and II only. This means that students are either learning to use scientific instruments (operate a microscope or an analytical balance), or they are given a set of step-by-step directions for a demonstration, and answer appropriate questions along the way.

As the sidebar states, often secondary students are merely going through the motions, not really understanding what is going on, but following formulas, and/or going through the activity stepwise. Readers are invited to review Figure 4.2 in order to assess their own laboratory assignments and to ask a question. How difficult would it be to transform just one of the standard textbook laboratories into an activity that is truly exploration?

Student 1: 'Do you understand it?"

Student 2: 'No."

Student 3: 'I don't either."

Student 4: 'I don't know either, but it's cool."

Student 1: 'Should we do a third one?"

Student 2: 'We don't know how to do the last one."

Student 3: 'We got a formula, isn't that enough?"

Student 2: 'Okay."

Rand, 1989

Elementary teachers already using hands-on science can provide laboratory-type exploration experiences. They may give students objects and provide the challenge: "Divide all the objects into two groups, those that are seeds and those that are not seeds." Here, students must examine all of the objects and make their own decisions. They must observe and classify, since using these skills are "built" into the activity. Students are required to carefully examine seeds and nonseeds. They examine all of the objects and make independent decisions based on criteria they establish. Some of these decisions may be "off the wall," but as students are taken through the learning cycle, misconceptions become clear and the young learner's naive thinking is challenged.

Concept Explanation: This is a period of organization in which students examine and try to make sense of the data they collected. Concept explanation is a real opportunity for cooperative groups. The teacher introduces the appropriate concept (or sometimes concepts) for what is occurring. The concept explanation part of the cycle is **teacher directed.** It is often in the form of a teacher-led discussion, but it need not be because diagrams, tables, graphs, pictures, films, and even additional activities are also used equally effectively. The purpose of the concept is to help students explain and understand their experience in a simple, clear, and direct manner. It is also a time when students can learn the language of the science they observed. When they explored, they probably worked from their own internal models of reality. As they observed a discrepant event, for instance, they may have noticed regularities--something was happening. The teacher can, at this point, introduce names for the events observed during the exploration phase. When students have had a chance to explore an event or a reaction, they are more likely to remember its name or the language of the phenomenon.

Concept Extension: In this phase of the learning cycle, the already introduced and partially (to fully) developed concept is used to apply, expand, modify, limit, or broaden the concept. This is a period of consolidation, providing both time and experiences for this to occur. The set of possible experiences is somewhat inexhaustible. The use of multiple activities are very similar to the concept exploration activities. They can include the same diverse array of activities: hands-on, active laboratory investigations, reading, problem sets, puzzles, and so on. Here it is possible to show how the concept learned can apply or interact with **other** ideas or concepts.

EVALUATION

As they learn, students need to know how well they are learning and understanding concepts. Teachers also want to know how well students are doing. Evaluation or assessment should be an ongoing process and must not be limited to the simplistic, fill in the "bubbles" on multiple choice answers. The rule of thumb is to "test what we value." We say we value the so-called higher order thinking skills, but traditionally do not assess them. The same dilemma is true of basic concepts and integrating concepts. Multiple choice tests are useful in that they are simple to score. This simplicity makes multiple choice tests the single most popular type of assessment instrument used in schools. Unfortunately, they are the least useful in measuring skills or in relating concepts. They do not convey the notion of what science is all about, nor do they challenge students to think about why they responded the way they did. The common use of standardized, commercial tests does not help the teacher assess his or her own goals because the tests were not developed with those goals in mind. Not only are commercial multiple choice tests limited in the types of knowledge and skills they are able to address, they fail to correspond to the curriculum they allegedly address. Most of all, multiple choice tests do not help teachers become more effective because they provide few clues on how students are perceiving, or what kinds of misconceptions they are harboring.

Getting Started in Science: A Blueprint for Elementary School Science Education, A Report from the National Center for Improving Science Education (1989), suggests ten criteria for improving and/or structuring formal student assessments (testing):

It is a truism that what gets tested, gets taught. If we test what we value, it will be taught.

1. Are there problems that require students to analyze situations; for example, does a particular statement make sense?

2. Does the test feature sets of problems that call for more than one step in arriving at (a) solution?

3. Are there some problems with more than one correct solution? Are students then, required to justify their answers?

4. Are there opportunities for students to use their own data and create their own problems?

5. Are students encouraged to use a variety of approaches to solve a problem?

6. Are there exercises that encourage students to first estimate the answer and then check the results?

7. Is the information in the problem accurate?

8. Are there exercises that ask students to first estimate the answer and then check the results?

9. Are students occasionally asked to find errors in problems or critique the way a problem is set up?

10. Are students given the opportunity to make up their own problems or questions?

11. Are they given the opportunity to solve a problem using the problem-solving skills of science?

12. Are we testing what we teach? Do our tests measure student attainment of all the goals, or merely those most easily measured?

TRANSPOSING OUTCOMES INTO CURRICULUM

Transposing outcomes into curriculum is no easy task. Unlike other disciplines, science does not easily lend itself to sequencing as does mathematics, language arts, or social studies. The only sequence that seems to be self-evident is the process dimension. Although one does not learn to think abstractly stepwise, certain thinking skills (process skills) can be used by children at the beginning of schooling. Thus, it is fairly easy for first graders to learn to classify, observe and infer, but almost impossible for them to do the more abstract, but related tasks of hypothesizing or conducting an experiment. The use of scientific models such as the atom or the carbon cycle are out of the question.

It is recommended that schools agree on a **limited** number of concepts, skills, and applications, and develop a scope and sequence from that core. To do this requires an agreement that the textbook is not an end in itself. In addition, there must be an agreement on a K-12 scope that employs and expands on the ends chosen. Thus, the curriculum that is developed will be thematic, one that is based on a variety of topics that include all of the aspects cited above and the state goals. Furthermore, the curriculum strands should expand and repeat throughout the grades, so that upon graduation, students will demonstrate an understanding of science as defined by the local educational agency.

For those who view the goals of understanding and problem-solving as important, the quality of assignments would count more than the number of topics assigned. Indicators for Measuring Mathematics and Science Education.

RAND, 1989

What should the curriculum look like: Both scientists and science educators agree that knowledge is growing so rapidly it is impossible to teach everything in detail. The United Kingdom, faced with the prospect of a national curriculum, came to the same conclusion and developed a limited series of goals, standards, and levels. An honest attempt was made to keep each of the three aspects of the British curriculum managable. It is important to remember that Minnesota has not developed, nor does it desire, a "state" curriculum.

Figures 4.3 to 4.5 provide some concrete examples of a scope and sequence based on the science outcomes. The illustrations show levels that are developmentally appropriate and that correspond to units and lessons in grades K-12. No attempt is made to match levels exactly to grades. Instead, the levels may be considered to be concrete, transitional, and formal examples of activities that correspond to the stated learner outcome.

Ideally, the sequence begins with the state board of education goals and moves to the more specific science outcomes. These outcomes include the essential learner outcomes that every district will use as they develop science learner outcomes on their PER cycle. Local curriculum planners are responsible for designing lessons and activities that emanate from the state science outcomes, as well as a rich science scope and sequence, K-12.

Remember, movement toward OBE is an evolutionary process. Don't bite off more than you can chew, but keep chewing!

It must be emphasized that moving toward OBE is a lengthy and sometimes difficult process. Ideally, each outcome strand or theme is directly tied to an exit framework and can be tracked from the bottom up. However, not all schools, administrators, and teachers are going to make the "leap" from a textbook-driven curriculum to one that is undergirded by outcomes. Therefore, it is recognized that, initially at least, one may want to work to course level or grade level objectives. Figure 4.3 provides an example of outcomes for a biology course, from State Board of Education level learner goals to a lesson outcome. Figures 4.4 and 4.5 are not course related. They illustrate an "ideal" framework, developmentally appropriate for a given grade/age span. They show a developmental, constructivist sequence that must be in place, K-12, so that students have an opportunity to integrate the essential outcomes.

If planners elect to use all or part of the self-assessment forms that follow, a clear pattern of the science program should emerge. First, data are collected from teachers as well as from other groups. The data are then summarized and analyzed. This provides a "report card" for each area of the science curriculum. It can be used to help curriculum planners decide on where the concept outcome belongs in the K-12 curriculum.

Finally, it is up to planners to decide how everything fits together, K-12. The questionnaires will help, as will the summaries and information collected at the end of the process. Most of all, planners will be provided with concrete data concerning their present program, and the level of support for it. What is missing? How far can one proceed in one leap? What size should the leap be? What inservice is needed to implement an outcome-based program? Will intermediate steps be needed? While self-assessment will not provide direct or easy answers to all of these questions, the process should provide enough data so the planners can make informed recommendations.

LEARNER GOAL: **State Board of Education Curriculum Rule, 3500.1060 Subpart 2, C1**
Each learner will be able to compare, differentiate, relate information and facts, and apply knowledge.

PROGRAM LEVEL LEARNER OUTCOME: **State Board of Education Curriculum Rule, 3500.1075 Subpart 8, A**
Opportunities will be provided for each student to learn to apply the basic scientific concept of cause and effect...

CONCEPT OUTCOME: **Model Learner Outcomes for Science Education, Chapter 3, A 7**
As a result of active involvement in science experiences, students will cite specific examples indicating that they understand that human activity affects the global environment positively and/or negatively.

COURSE OUTCOME (Biology): **(Locally Developed)**
Students will understand the interrelationships of predator/prey, food chain, niche, and environment.

UNIT OUTCOME (Biology): **(Locally Developed)**
Students will demonstrate the effects of population growth.

LESSON OUTCOME (Biology): **(Locally Developed)**
Using a yeast culture, students will design and perform an experiment that illustrates logarithmic population growth. They will postulate a hypothesis to explain each step in the growth curve. **Excursion:** They may determine the ideal conditions for maximum production of ethyl alcohol, a by-product of yeast metabolism.

FIGURE 4.3.
Example of Outcomes - Biology

LEARNER GOAL: **State Board of Education Curriculum Rule 3500.1060 Subpart 2, A1**
To effectively participate in learning activities, each learner will master reading literacy to gather information and data, gain perspective and understanding...

PROGRAM OUTCOME: **State Board of Education Curriculum Rule, 3500.1075 Subpart 8, B**
Opportunities will be provided for each student to apply the higher order thinking skill of observing...

CONCEPT OUTCOME: **Model Learner Outcomes for Science Education, Chapter 3, B1**
As a result of active involvement in science experiences, students will demonstrate they can employ all the senses to collect information concerning objects, systems, and events.

LEVELS: **(Locally Developed)**

ELEMENTARY:	Students are able to describe objects such as rocks, shoes, tables, in terms of their physical properties.
MIDDLE:	Students will be able to design surveys and other means to explore events. Students will be able to compare physical properties of two objects, living or non-living, such as two insects or minerals, and note patterns or regularities in their findings.
SECONDARY:	Make and record observations relevant to an investigation they conduct. Recognize discrepant events that occur during an investigation. Make observations and justify them in light of data. Detect unreliability and variability in observations, measurements, and techniques.

FIGURE 4.4.
Example One
Developmental Outcome Sequence

LEARNER GOAL: **State Board of Education Curriculum Rule 3500.1060 Subpart 2, B7**

To provide a foundation for meaning in life, each learner will accumulate and apply knowledge and develop the understanding to know the impact of human life on nature and the impact of natural phenomena on human life.

PROGRAM OUTCOME: **State Board of Education Curriculum Rule 3500.1075 Subpart 8E**

Opportunities will be provided for each student to learn to understand the personal dimensions of science and technology and how to apply concepts and thinking skills to everyday life, to develop the ability to apply the basic scientific concepts to their technological world, to understand major issues facing society...

CONCEPT OUTCOME: **Model Learner Outcomes for Science Education "E-3"**

As a result of active involvement in science experiences, students will be able to recognize and cite examples of the tradeoffs implicit in the resolution of a societal issue.

LEVELS – **(Locally Developed)**

ELEMENTARY: Students can investigate the extent to which a selection of everyday waste products such as plants, cans, plastic, and paper decay naturally.

Students keep records of these observations and, in groups, decide how to improve their school play area.

MIDDLE: Students make simple water tests from areas in their general locality. Determine how polluted their lakes and streams are. Students should be able to observe the different types of pollutants, solids, dissolved substances.

Students should test local water samples for pH over the span of one year, write a report, draw conclusions.

Using data supplied by secondary sources, determine the extent that the atmosphere is polluted by various means, and that pollution is transported to other areas.

SECONDARY: Students should be able to conduct a study using primary or secondary information sources to determine the extent that natural resources are exploited.

Using the same sources of information, compile a "damage" report that includes practical recommendations for remediation.

After weighing the merits and disadvantages of various waste disposal systems, determine those which are the safest for the environment and human beings.

Students should be able to distinguish between biased and objective "evidence." They should be able to base conclusions on objective evidence. *

*** Some of the above examples are modified from the United Kingdom Science Standards.**

FIGURE 4.5.

Example Two

Developmental Outcome Sequence

Appendices

INCREASING OPTIONS TO PLAY THE SCIENTIFIC-MATHEMATICAL GAME: TOWARD A MULTICULTURAL/GENDER FAIR/DISABILITY SENSITIVE SCIENCE EDUCATION CURRICULUM

OVERVIEW

In the past few years, there has been increasing concern about the under-representation of diverse racial/cultural groups, women, and the disabled in quantitatively based disciplines such as engineering, mathematics, computer science, the physical sciences, and the biological sciences. The destructive pathways that have led to such underrepresentation among those who do science are both direct and indirect and include sociological, cultural, and educational factors. Some researchers claim that intrinsic biological differences between the sexes determine intellectual ability in science. In "Sex Differences in Intellectual Ability," Dr. Meredith M. Kimball, Simon Fraser University, British Columbia, point out that:

> *" the exact origin of any sex differences inability might be unimportant were it not for the tendency of educators, governments, and the public in general to accept the absence of girls from science and mathematics as 'natural,' suggesting that 'nature' is somewhat responsible for this lack of interest and achievement, and that we should not interfere... We see this point of view reflected in comments such as that made by a Newsweek journalist in an article on sex differences in mathematical ability, 'if (the sex differences) are genetic we must learn to accept them.'*

FROM: *Who Turns the Wheel?* Proceedings of a Workshop in Science Education of Women in Canada, Science Council of Canada, 1982.

Literature on the effects of elementary and secondary institutions indicates the importance of the early years of education in increasing the representation of women and minorities in the quantitative disciplines. The task before science educators and, in a wider and more pervasive sense, schools, is to enlarge such restricted horizons and to provide compensating resources and encouragement for students (girls and minorities) who do not have them outside school.

The context for science and mathematics education in grades K-12 very much lies in the word "supportive." A criterion that should be used in investigating the science curriculum is how supportive it is for young women, minority students and the handicapped. This includes but is not limited to:

-- Encouraging all students to acquire the academic skills they need to major in science at a college or university;

-- Promoting career awareness so that all students may learn of opportunities in mathematics and science-related professions early enough to prepare for them;

-- Provide educational enrichment activities that can contribute to preparation, development and commitment of students for science-related careers;

It is clear that the K-12 science education program should be multicultural, non-sexist and disability sensitive. Such perspectives should quite literally influence and infuse all classroom work. In 1981, the Educational Equity Section, Department of Public Instruction, State of Iowa, prepared a checklist to be used in the review of science curriculum programs. The purpose of the Multicultural, Non-Sexist, and Disability Sensitive in Iowa Schools-Math and Science checklist is "to determine the degree to which classrooms are consistent with the basic concepts of multicultural, nonsexist and disability sensitive education." The checklist is a general guide and a profound consciousness-raiser. Many of the questions in the survey which follows are taken from it. Some items have been modified.

In Multicultural Nonsexist Education in Iowa Schools, multicultural education and nonsexist education are defined as follows:

Multicultural Education: the educational processes which promote the understanding and appreciation of the cultural diversity of our pluralistic society. Within the total multicultural educational process, special emphasis shall be placed on the following groups: Asian American, Afro-American, Hispanic American, Native American, and the handicapped. The educational program shall be characterized by practices which provide equal opportunity for all participants regardless of race, color, age, national origin, religion, or handicap.

Non-Sexist Education: the educational processes which foster the knowledge of, and respect and appreciation for, the historical and contemporary contributions of men and women to society, as well as those educational processes that reflect the wide variety of roles open to both men and women. The educational program shall be characterized by practices which provide equal opportunity to both sexes.

Directions:

1. In the spaces provided, participants should indicate whether he or she agrees (yes) or disagrees (no) with the statement.

2. When participants are finished, tally the responses, either item or by clusters of ideas. Use this opportunity for review and discussion. What are some of the concerns? Insights?

3. After each cluster of items, space is provided for adding your own questions.

4. Subsection E, contains questions that ask for honest self-assessment. These answers do not need to be discussed directly with the group although it is likely they will influence group discussion.

5. After the items have been rated and discussed, use the matrix format provided to develop an overall rating for the status of multicultural, non-sexist education in science for your school/school district. (See "User's Guide to a Matrix Assessment").

6. The matrix can be used to focus on the extent to which instruction in science is meeting the needs of all students in your school. There are many questions that can be and need to be considered when incorporating multicultural, non-sexist, disability sensitive concerns into teaching and learning. An abbreviated list designed to help summarize discussion is found in the sheet titled "Multicultural Non-sexist Education and Science Education: Considerations."

A. The School

1. Are there diverse role models (male-female, diverse cultures/races) teaching science at both the elementary and secondary levels?

____Yes ____No

a. If the answer is no, what has caused this to happen? Are there any strategies for changing this pattern? If no, what are some appropriate strategies?
b. If the answer is no, what impact does this have on the strategies that will be used to achieve multicultural, non-sexist science objectives?

2. Are there disabled employees on the school district staff who may serve as role models for students?

____Yes ____No

3. Are there diverse student enrollments (male-female balance and ethnic and racial diversity similar to that found in the district) in all elementary and secondary science courses?

____ Yes ____ No

a. If the answer is no, what has caused this to happen? Are there long-range strategies for changing this pattern? If no, what are some appropriate strategies?
b. If the answer is no, what impact does this have on the strategies that will be used to achieve multicultural, non-sexist science objectives?

4. Are scheduling practices used which may result in sex-typed enrollments (80 percent or more of one sex) or the relative isolation of racial/cultural groups and the disabled?

____Yes ____No

5. Do girls who wish to pursue advanced science courses find their fears that "girls don't become scientists" reinforced clearly by the ratio of boys and girls in the classroom?

____Yes ____No

6. Are science courses given titles which are more meaningful to one sex or cultural group?

____Yes ____No

7. Are course descriptions free of bias or stereotyping?

____Yes ____No

8. Has there been meaningful interaction between science teachers and the personnel within the district who are responsible for the implementation of multicultural, non-sexist education?

____Yes ____No

9. Has in-service on multicultural, non-sexist approaches to the science curriculum been provided for all elementary and secondary science teachers?

____Yes ____No

10. Have the district administrators incorporated multicultural, non-sexist education concepts into staff evaluation procedures?

____Yes ____No

11. Have you interviewed students, say, in ninth and twelfth grade, for example, about course preferences and personal reasons for preferences; important things that need to be discussed in science; areas where the school has different expectations for boys than it has for girls and what those different expectations are; and their rating of the usefulness of mathematics and science?

____Yes ____No

12. Is there an organized effort to prepare minority, female, and handicapped students for science based fields of study? This may include tutoring; independent study groups, peer support systems; academies, university and career counseling; special field trips; and summer employment/internship programs.

____Yes ____No

13. Are there present education programs which help parents to become aware of the possibilities of science in their children's future?

____Yes ____No

14. Do such program offer suggestions and activities for parents to use in nurturing children's interest in mathematics and science?

____Yes ____No

B. Curriculum Content

1. Does the science curriculum include units/activities which explore the importance of basic scientific skills in broadening career options and enhancing future earning capacity?

____Yes ____No

2. Does the science curriculum include units/activities which cause students to become aware of their attitudes toward science and which may lessen the science anxiety that many students, especially female and minority students might be experiencing?

____Yes ____No

3. Does the science curriculum include units/activities which explore related careers in non-stereotypic ways?

____Yes ____No

4. Does the science curriculum include content on the contribution of diverse racial/cultural groups, both women and men, and the handicapped to the field of science?

____Yes ____No

4. Are the content areas, mentioned in Section B included in science instructional materials?

____Yes ____ No

5. Do the materials tend to reinforce stereotypes about cultural/racial groups, men and women or the handicapped?

____Yes ____ No

6. Do examples and word problems use both Anglo origin names such as Mary Jones, Bob Smith, and James Baker, as well as names of non-Anglo origin such as Juanita Ramos, Mitsue Yashima, or Jonathan Youngbear?

____Yes ____ No

7. Have multicultural, non-sexist criteria been integrated into the science instructional materials selection process at a district level?

____Yes ____No

8. Are problems of combining career and family explicityly addressed, and are clear models of women who are successful at both career and marriage provided?

____Yes ____ No

D. The Classroom

1. Do classroom teachers avoid using language patterns which may be sexist or ethnocentric?

____Yes ____ No

2. Do teacher expectations affect the performance and enrollment patterns of women, minorities, and the handicapped in science?

____Yes ____ No

3. Are classroom management strategies and role assignments used which reinforce multicultural, non-sexist student behavior?

Yes No

4. Do all students have equal experience with the instruments, materials, and techniques of science?

____Yes ____No

5. Are students alerted to stereotyping when it occurs in instructional materials?

____Yes ____No

6. Do all students have equal opportunities in taking a variety of science related field trips and other extracurricular science experiences?

____Yes ____ No

7. Are persons of diverse cultural/racial groups, men and women in both trational and non-traditional roles, and handicapped individuals used as resource persons in the classroom?

____Yes ____ No

5. Do life science and biology curricula include content and experiences which provide students with a basic awareness of:

- the common characteristic of all human beings? ____ Yes ____ No
- human adaptation in a biosocial context? ____ Yes ____ No
- the role science can potentially play in preventing racism or racial equality and respect?

  ____ Yes ____ No
- sex determination and sex differentiation in humans? ____ Yes ____ No
- attitudes toward people who may look or act differently from most other people?

  ____ Yes ____ No
- view and implications of sexual stereotyping, gender identity and gender role, and how science comes to be perceived as a male domain?

  ____ Yes ____ No
- the role science can play in promoting sexual equality and how it may also be misused as a basis for promoting sexism?

  ____ Yes ____ No

C. Instructional Materials

1a. Are illustrations in science textbooks, supplementary materials, audiovisual aids, and on bulletin boards representative of the cultural/racial diversity in the United States as well as the roles open to both men and women in today's society?

____ Yes ____ No

1b. Are handicapped persons represented? ____ Yes ____ No

2a. Are both women and men, diverse cultural/racial groups and the handicapped shown in both active and passive roles in doing science?

____ Yes ____ No

2b. Traditional and non-traditional roles? ____ Yes ____ No

2c. Domestic and non-domestic roles? ____ Yes ____ No

3. Are instructional materials free of ethnocentric or sexist language patterns which may make implications about persons or groups solely based upon their culture, race, sex, or disability?

____ Yes ____ No

8. Is there a balance between large group, small group, and individual activities in the classroom schedule so that all students, regardless of sex, race/culture, and handicapped are encouraged to become integrally involved?

____Yes ____No

9. Are the bulletin boards and teacher-made displays in the classroom representative of the cultural/racial diversity in the United States and roles open to both men and women?

____Yes ____No

10. Have classroom teachers alerted the counseling staff to possible multicultural, nonsexist guidance techniques which are relevant to course work and career preparation in science?

____Yes ____No

11. Are students exposed to people who use mathematics and science in the workplace?

____Yes ____No

12. Are tests culturally fair, i.e., do they assess the skills and content actually taught?

____Yes ____No

13. Are all children encouraged through teacher feedback and guidance to persevere as they work their way through appropriately challenging problems and situations?

____Yes ____No

14. Are minority and women students actively encouraged to take the more challenging educational path?

____Yes ____No

15. Is there a list of resource material designed to help you implement multicultural, nonsexist science education? Such a list might include information about newsletters/periodicals ("Women Chemists," "Women in Forestry," "CML Newsletter"); associations and committees of or for women, minorities, and the handicapped in science, engineering, mathematics, and medicine (e.g., Native American Science Education Association, American Indian Science and Engineering Society, Association of Handicapped Student Services Providers in Postsecondary Education, AAAS Project on the Handicapped in Science, Minority Participation in the Earth Sciences; NABT Section on the Role and Status of Women in Science Education); audiovisual materials; biographies of minorities, women and the handicapped; and curriculum programs.

____Yes ____No

16. Are there discussions of male/female stereotypes in classrooms?

____Yes ____No

17. Is it expected that every youngster be fully involved in all of the science procedures of a science learning activity?

____Yes ____No

E. Teacher Expectations

1. Is there an overrepresentation of minority students and/or girls among your low achievers?

____ Yes ____ No

2. If so, do you:

a. Interact more with high achievers and ignore and interrupt low achievers more frequently?

____ Yes ____ No

b. As more and high level questions of high achievers and provide low achievers with questions that require only simple recall?

____ Yes ____ No

c. Follow up with probing questions for high achievers and call on someone else if a low achiever is unable to provide a prompt, accurate response?

____ Yes ____ No

d. Provide a longer wait time for high achievers to respond to a question and cut off response time for low achievers who hesitate?

____ Yes ____ No

e. Seat high achievers closer to the teacher's usual position and cluster low achievers further away?

____ Yes ____ No

f. Praise high achievers more often and criticize low achievers more frequently?

____ Yes ____ No

g. Provide supportive communications for high achievers and engage in dominating behaviors with low achievers?

____ Yes ____ No

h. Provide high achievers with detailed feedback and give less frequent, less accurate, and less precise feedback to low achievers?

____ Yes ____ No

i. Demand more work and effort from high achievers and accept less from low achievers?

____ Yes ____ No

3. Do you interact more with high-achieving boys that with high-achieving girls?

____ Yes ____ No

4. Please answer the following situation items.

What do you do when:
- A girl begins a thoughtful explanation and a boy interrupts?

- Students organize themselves into laboratory groups, and a girl reaches for a paper and pencil to take notes?

- Students assign themselves tasks and responsibilities during laboratory work with regard to race/cultural commitments and sex (boy/girl) differences?

- A young woman tells you that her mother has attempted to dissuade her from choosing a career in science?

- A disabled and non-disabled student are working together. The disabled student is overshadowed and/or patronized by the will-intending non-disabled student?

MULTICULTURAL NONSEXIST EDUCATION AND SCIENCE EDUCATION: CONSIDERATIONS

What do we mean by multicultural non-sexist education in science?

What are we already doing?

Are adequate multicultural, non-sexist, disability sensitive science education programs provided for all of our students?

What do we do that inhibits or restricts the achievement of multicultural, non-sexist, disability sensitive education?

What are the implications for in-service programs, curriculum development, long-term commitment, and support requirements (human and financial)?

USER'S GUIDE TO A MATRIX ASSESSMENT

In the preceding section, a step-by-step process has been described for analyzing the science curriculum. An assessment instrument is provided for each section you evaluate: nature of science; curriculum; physical facilities; laboratory safety; support for science education within your district; student, parent, and teacher perceptions of science education; equity; and learner outcomes.

The evaluation method is simple. The program is assessed in terms of **OUGHT** and **IS**, both for your teaching situation and your school. The rating scales used are:

OUGHT to be achieved in the Science Education Program

5 - of utmost value
4 - of significant value
3 - of medium value
2 - of insignificant value
1 - of negative value

IS achieved in the Science Education Program

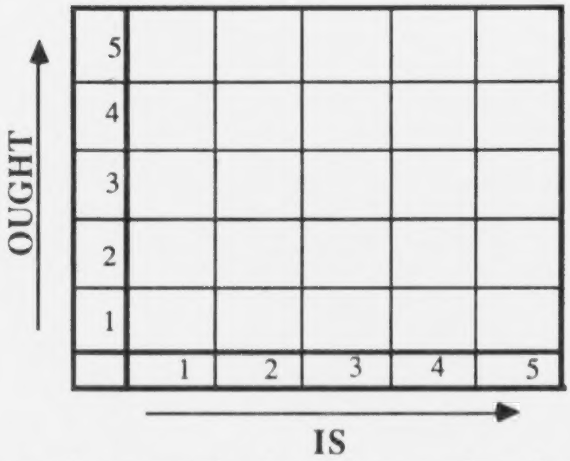
5 - extremely high level
4 - above average
3 - on the average
2 - less than average
1 - avoided or non-existent

Two matrix formats, a large and a small version, are included at the end of this section. Use them as blackline masters to make copies and transparencies.

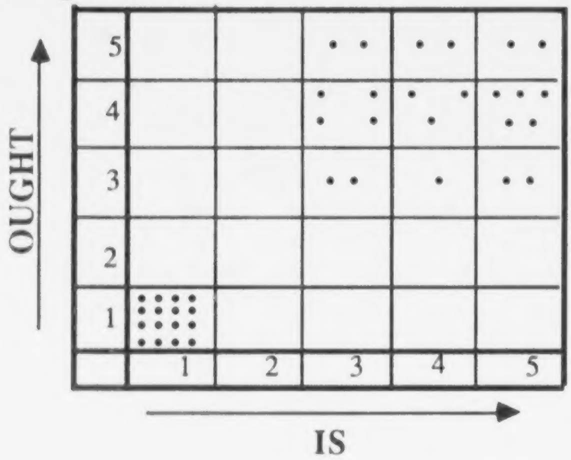
Directions

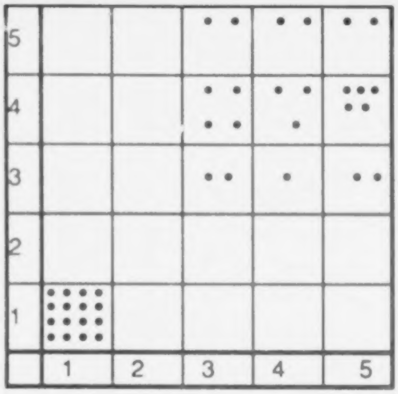
Make copies of the assessment instruments and the small and large matrixes. Each individual on the task force or committee should answer each questionnaire that relates to her or his level and complete the small matrixes for each assessment instrument used. Some items are yes/no only and do not need a matrix. When individual matrixes are completed for each assessment section, combine the committee results onto the large matrix to facilitate discussion. Once group results have been pooled, patterns will emerge as illustrated below. The large matrix can be made into a transparency.

You will note that **OUGHT** is on the vertical and that **IS** is on the horizontal axis. For each statement, circle the rating you wish to assign to **OUGHT** . Do the same for **IS.** To score this item, place an "X" in the box where the two ratings intersect. Two examples follow. In Matrix "A" an important goal is being achieved: it is one that ought to be achieved and is achieved, but only moderately. Matrix "B" raises significant questions about the achievement of a goal; it is one that is achieved but ought not to be achieved.

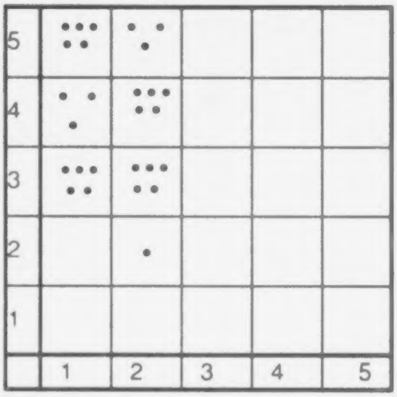


Occasionally, you may be uncertain about the meaning of an item or how it applies to your school or teaching situation.

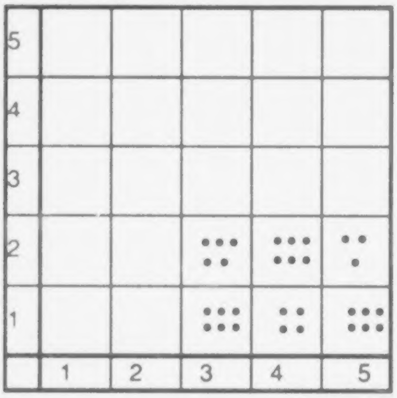




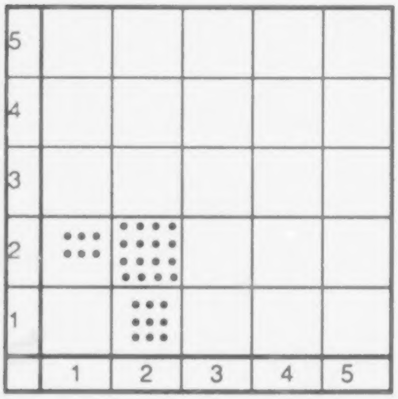
Responses in this area indicate important goals being achieved and in matrix cell 1, 1, undesirable goals being achieved.



Responses in this area indicate achievement is short of expectations.



Responses in this area indicate that more time, energy, or resources may be spent than is justified.



Responses in this area indicate items that probably deserve little or no future attention.

OUGHT

5					
4					
3					
2					
1					
	1	2	3	4	5

IS

Use this matrix to make a transparency to use during your in-service instruction. You may also use this matrix as a summary matrix for an entire module.

PERCEPTIONS

OVERVIEW

The Planning, Evaluation, and Reporting law (PER) specifies that a representative curriculum advisory committee be established to facilitate decisions concerning curriculum planning and evaluation. This section provides some tools that can be used to meet that obligation. While the law does not require student representation, student perceptions of the science program would appear to be equally valuable.

This section is intended to broaden the district's view of its educational program by surveying students, parents, and teachers. The survey instrument attempts to cover many aspects of schooling. The survey is divided into two sub-sections: Elementary (K-6) and Secondary (7-12). Some practical considerations are listed below:

--Review these lists carefully before you use them. You may want to add, delete, or modify items in order to further tailor the assessment to your needs. You may want to differentiate junior high/middle school from the high school. We also suggest that when you have finished reviewing/modifying this instrument, that teachers be asked their opinions for appropriate items. This will provide useful, comparative data.

Representative committees of students and parents should complete the assessment. The elementary items are most appropriate for the sixth-grade; although, the responses are intended to reflect the entire K-6 experience.

--Remember, as in the previous assessment instrument, this is a two-fold process. The first category is perceived desirability, OUGHT, and the perceived achievement, IS, for each variable. You can simplify the process by having students place numbers from 1 (lowest) to 5 (highest) next to the items to make the process more simple, or you can ask participants to use the matrix charts found on **pages 12-14.**

--When all assessments (student/parent and teachers) are final, summarize the data on a copy of the large matrix found on page (?). The data can be best viewed and digested if they all transferred to an overhead transparency. Then, the committee can discuss the patterns, areas of agreement, or irregularities. When used this way, there may be two or more perceptions that emerge. Which is real? How can perceptions be rectified? What ought to be done? It is also highly desirable to bring in students and parents for a round table discussion of the results. Although educators are the experts, outside viewpoints are a useful and inexpensive way to ascertain how others view and think about the science program.

STUDENTS

A. Elementary, K-6

O	I	
____	____	1. Teachers appear to enjoy teaching science.
____	____	2. As a part of the science program, I have to show that I know how to use scientific equipment and instruments.
____	____	3. We are regularly asked to make hypotheses.
____	____	4. We identify the variables in the experiments we do.
____	____	5. We collect, organize, and record data in tables.
____	____	6. We use histograms (or graphs) to show results.
____	____	7. We draw tentative conclusions (make inferences) from histograms (or graphs).
____	____	8. We work in pairs of small groups in science classes.
____	____	9. Teachers frequently ask us to support our answers with evidence.
____	____	10. There are enough supplies and pieces of science equipment to go around.
____	____	11. There are enough textbooks or required reading materials for each student to have a copy.
____	____	12. We take at least one science field trip each year.
____	____	13. In science classes we become familiar with science-related careers.
____	____	14. In science, at least once a week, we do a laboratory activity.
____	____	15. We are given opportunities in science classes to handle the materials of science, e.g., equipment and apparatus.
____	____	16. Teachers ask us what we think about what we study and which kinds of science activities we prefer.

A. Elementary, K-6 (con't)

O	I	
____	____	17. At least once per year, we are given an opportunity to pursue our own investigations in science.
____	____	18. Most of the time in science is spent in discussion, reading the textbook, and doing worksheets.

Comments:

B. Secondary, 7-12

O	I	
____	____	1. As part of our science courses we are taught safety procedures both as the beginning and throughout the schools year.
____	____	2. Students are encouraged to take more than the minimum number of science courses.
____	____	3. The science rooms are organized so that when I need single pieces of equipment I know where to find them.
____	____	4. As part of our grade, we must demonstrate the ability to use the equipment and instruments of science.
____	____	5. We are required to make hypotheses in our science class.
____	____	6. We are required to be able to put information into tables and graphs.
____	____	7. We are required to be able to read information from tables and graphs.
____	____	8. We are required to observe similarities and differences between two or more events.
____	____	9. We are required to collect information we observe and to find patterns in or explain our observations.
____	____	10. Our tests and quizzes include not only questions about factual information but also questions that ask us to interpret information.

B. Secondary, 7-12 (con't)

O **I**

____ ____ 11. At least once a year (or once per course), under the supervision of our teacher, we design our own experiment.

____ ____ 12. We are routinely asked to make predictions about events.

____ ____ 13. At least once in each science course we are asked to design an investigation.

____ ____ 14. Occasionally, when we are asked what we would do to obtain better data from an experiment, we repeat the experiment.

____ ____ 15. Teachers place a lot of emphasis on ideas and how they are related to each other.

____ ____ 16. There are opportunities to use computers in science class, e.g., construction of graphs and databases; monitoring measurements; storing, retrieving, and organizing date; as a tool for modeling and simulation; and games.

____ ____ 17. The science teachers enjoy teaching science.

____ ____ 18. In our science classes, information and activities are related to science in our personal lives, careers in science and technology, and societal problems related to science and technology.

____ ____ 19. We take at least on science-related field trip in each science course.

20. Teachers ask students to justify and explain their ideas.

____ ____ 21. Teachers allow time after asking a question so that students have a chance to think about the answer.

____ ____ 22. Our science teachers encourage cooperation, e.g., students work in pairs/small groups, students respond to comments and questions of other students, students help each other analyze and solve problems.

____ ____ 23. Most of the time, science teachers ask both single-answer questions as frequently as open-ended, thought provoking questions.

Comments:

PARENTS

A. Elementary, K-6

O I

____ ____ 1. The science instruction offered by the school is appropriate.

____ ____ 2. Throughout elementary school, the science topics studied appear to be well balanced among the Life sciences, earth sciences, and physical sciences.

____ ____ 3. Children's science experiences are consistent with the experimental nature of science, i.e., the science program provides hands-on experiences with real objects.

____ ____ 4. In the elementary science program, children are introduced to fundamental concepts of science and given time to discover and understand their meaning.

____ ____ 5. Children are given sufficient direct experiences to become confident in making their own observatins and raising their own questions.

____ ____ 6. Children engage in discussions of their ideas and observations.

____ ____ 7. Children apply what they learn in science class to everyday, familiar objects and events.

____ ____ 8. Students are evaluated in scienc on both knowledge and skills (observing, classifying, measuring, prediciting, inferring, recording and analyzing data, developing and testing hypotheses, designing and conducting experiments).

____ ____ 9. The school holds programs to assist parents with helping their children in science.

____ ____ 10. The science program has been modified to be of maximum benefit to the academically gifted and talented and to children with learning difficulties.

____ ____ 11. Parents or other community members are asked to assist teachers as laboratory aides during science lessons, or for extracurricular activities, e.g., science fair projects, after school science programs.

____ ____ 12. The science learned by children -- knowledge and activities -- is appropriate to the age, mental ability, and skills of the students.

A. Elementary, K-6 (con't)

O I

____ ____ 13. My child comments about how much he or she enjoys science class.

____ ____ 14. Teachers provide opportunities for students to ask questions about science and then to find answers to these questions.

Comments:

B. Secondary, 7-12

O I

____ ____ 1. The science program encourages students to *think* like scientists rather than memorize a lot of unrelated facts.

____ ____ 2. There is an emphasis in science on understanding concepts and in learning how they are related to one another.

____ ____ 3. The science program has been modified to be of maximum benefit to the academically gifted and to children with learning difficulties.

____ ____ 4. In general, my child is satisfied with what she or he learns and does in science class.

____ ____ 5. The science education program provides students with information about careers in technology and science-related fields.

____ ____ 6. The science teachers are both enthusiastic and knowledgeable.

____ ____ 7. The science teachers place a great deal of emphasis on scientific reasoning.

____ ____ 8. In science, students explore some of the science and technology problems related to society.

____ ____ 9. Science courses are related to practical, personal concerns of students.

____ ____ 10. Students who do well in science are encouraged to take more than the required number of science courses.

B. Secondary, 7-12

O **I**

_____ _____ 11. Laboratory experiences are an important part of science instruction.

_____ _____ 12. Our school has established a science advisory committee which includes scientists, community leaders, parents, and teachers.

_____ _____ 13. Community members, students, and parents are all involved in major decisions affecting the science program such as textbook adoptions, course modifications, and graduation requirements.

_____ _____ 14. My child's school holds programs to assist parents with helping their children in science.

_____ _____ 15. Students are evaluated in science on what they know as well as their ability to use the skills and instruments of science.

_____ _____ 16. Parents are informed about the science program, e.g., special activities, contemplated changes, textbook adoption, innovative programs.

_____ _____ 17. I have a clear understanding of what is expected of my children in science classes.

_____ _____ 18. I have been informed about acceptable laboratory safety practices and training my children have received to prepare them for work in the laboratory.

_____ _____ 19. I have examined a student laboratory safety contract.

_____ _____ 20. The science program integrates intellectual skills and practical hands-on experiences with the materials and instruments of science.

_____ _____ 21. Courses in high school science emphasize learning concepts and skills for academic study beyond high school.

_____ _____ 22. In science classes, students are expected to back up claims by evidence.

_____ _____ 23. Science teachers give adequate reasons for accepting or rejecting a student's statement or response.

_____ _____ 24. In discussions, suggestions, questions, and statements by students are honored.

_____ _____ 25. The science program actively encourages all students to pursue careers in science, e.g., learning units and activities explore science-related careers in ways that show the contributions of females, minorities, and the disabled.

Comments:

THE SCIENCE EDUCATION CURRICULUM

OVERVIEW

This section is divided into three parts: 1) Elementary, K-6, 2) Secondary, 7-12 and 3) Elementary and Secondary, K-12. The first part is to be completed by the elementary curriculum committee, the second part by the secondary curriculum committee and the third part by **both committees.** There are two subsections in each part: A) Budget, and B) Administrative Support.

Directions

1. In the blanks provided in front of each item or on the matrix provided, indicate whether the item OUGHT (O) to be achieved and whether is IS (I) achieved in your school/district. Use the rating scales described in "A User's Guide to a Matrix Assessment" **(Pg.11).** If you use the matrix, be sure to label and number the items.

2. Review and discuss your individual responses with another person, then in groups of four, eight, and so on until the entire group has reached agreement on the statements. At each step you can add to the list of statements, combine, modify, or omit statements. The large matrix provided may be especially useful as the group becomes larger.

3. The space under the comments heading is to be used to describe additional information needed, to clarify or amplify items in the checklist, to explain judgment and ratings, questions raised, and most importantly, evaluative comments and implications for the science education curriculum/program in your school.

ELEMENTARY, K-6

A. Budget

O I

____ ____ 1. Our budget is sufficient to allow the purchase of enough supplies, materials, and equipment needed for an activity-based science program.

____ ____ 2. Teachers in our school are involved in the development of the science budget.

____ ____ 3. There are petty cash funds or teachers are reimbursed when it is necessary to purchase special materials for science throughout the school year.

____ ____ 4. There is a budget sufficient for at least one science-related field trip each year at each grade level.

____ ____ 5. The staff knows how much it costs to educate a child currently in science.

____ ____ 6. There is a budget for support of extracurricular activities, e.g., participation in science fairs.

Comments:

A. Curriculum Planning (con't)

O **I**

_____ _____ 7. The development of the curriculum plan included a full range of stakeholders: teachers, parents, students, administrators, and others who are accountable for its implementation, maintenance, and evaluation.

_____ _____ 8. Local curriculum guidelines have been developed. Elementary teachers were involved in the development of these guidelines.

_____ _____ 9. The science curriculum plan is consistent with the Minnesota Department of Education goals and subgoals of public educaiton in the State of Minnesota. (The learner outcomes in science are subgoals).

_____ _____ 10. The science curriculum plan specifies the amount of time that should be spent on science on a daily or weekly basis. The weekly amount of time for science means for students in grades 4-6.

Comments:

B. Classroom

O I

_____ _____ 1. The curriculum encourages children to think like scientists rather than memorize a lot of facts.

_____ _____ 2. Learning activities in science are arranged in order of increasing complexity and abstraction.

_____ _____ 3. The science curriculum deliberately and profusely makes use of art, writing, mathematics, social studies, and reading.

_____ _____ 4. Our curriculum values human creativity and originality. These values are promoted by including inventing/invention fairs in which students are invited and challenged to become inventors.

_____ _____ 5. The curriclum accords the student the right to be wrong, to learn from mistakes by retracing or repeating procedures.

_____ _____ 6. The science program emphasizes direct firsthand experiences with science materials and equipment (hands-on science), inquiry strategies, and student decision making.

B. Classroom (con't)

O I

____ ____ 7. Instructional materials which teach science process skills–observing, classifying, measuring, communicating, defining operationally, prediciting, inferring, controlling variables–are used with all students.

____ ____ 8. Content is balanced among the life sciences, earth sciences, and physical sciences.

____ ____ 9. The science content and processess used with students are suited to their cognitive developmental abilities and physical capacities.

____ ____ 10. The science program is determined by the textbooks and activity manuals adopted for use.

____ ____ 11. The curriculum provides enrichment opportunities for students such as cooperative learning experiences with secondary schools, businesses, other institutions, and the community.

____ ____ 12. The instructional materials direct students to work using the processes of science rather than the "cookbook" approach to laboratory investigations.

____ ____ 13. The curriculum is designed to inform students about careers in science and technology.

____ ____ 14. The curriculum is designed to be taught in cooperative small groups.

____ ____ 15. Scientific information about the participation of women and minority members in science and technology is provided to students.

____ ____ 16. The actual science curriculum taught reflects the concepts, processes, and values defined in the K-6 curriculum plan.

____ ____ 17. The curriculum ties classroom science to real world issues, e.g., is personally relevant and applicable–contributes to the individual's survival and well being and, e.g., consumers and health issues and explores science related societal issues–contributes to the quality of life, e.g., custodians of the environment and ways science and technology change the way we live.

____ ____ 18. Ideas and/or activities from the exemplary major national curriculum materials, particularly the National Science Foundation sponsored programs during the 1960's, have been incorporated into the curriculum.

____ ____ 19. Science is used as a vehicle for bringing mathematics into the "real" world, e.g., using mathematical techniques to display and extract information from data.

B. Classroom (con't)

O I

______ ______ 20. Science is used as a vewhicle for showing uses of computers, e.g., the use of databases, recording temperature changes over a long period of time, and collecting data and making graphs.

______ ______ 21. Computers are used to teach specific science skills or concepts.

______ ______ 22. Information about science careers is included as part of each unit.

Comments:

C. Curriculum Evaluation

O I

______ ______ 1. The science education curriculum plan in our school is evaluated and modifications are made in it by a science curriculum committee periodically.

______ ______ 2. When modifications are made in the science education curriculum plan, the educational advantages to be gained by the changes are specified.

______ ______ 3. Students are asked their opinion of the effectiveness of instructional materials and activities used in science.

______ ______ 4. Teachers keep records of activities in science that both work and don't work and their reasons.

______ ______ 5. The assessment framework includes performance measures in science (appropriate to age, grade, and experience levels), e.g., using scientific equipment and measuring instruments, making and interpreting observations, classifying objects, recording information from graphs and charts, placing information in graphs and charts, estimating, predicting, and interpreting information.

______ ______ 6. Evaluation procedures are consistent with science objectives.

______ ______ 7. A locally developed, multiple choice, criterion-referenced test is administered late in the school year to sixth-grade students. It covers the processes and content that students have covered in grades 3-6. The test is used to improve the quality of the program.

C. Curriculum Evaluation (con't)

O	I	
		8. At the end of instructional units in science, students exhibit proficiency on measures that are consistent with the objectives.
		9. Each year, parents are asked for their comments about the science education program.
		10. Students suggest ways in which their work in science is to be evaluated.
		11. Students and parents know how they are being evaluated in science.
		12. Attempts are made to assess student attitudes about science.
		13. An alternative grading system has been developed for science that is consistent with an activity-centered program. Teachers, parents, and students understand it.
		14. Valid means, e.g., standardized tests, are used to identify students with special talent and interest in science.
		15. Students who do will in science are encouraged to participate in extracurricular science activities if available.
		16. Periodically, the elementary science education program is evaluated by someone outside the school/school system, e.g., by the state science consultant, the science coordinator from another district, or by a college faculty member.
		17. Periodic reports about the science education program are made to the Board of Education.

Comments:

ELEMENTARY AND SECONDARY, K-12

O	I	
____	____	1. There is a K-12 Curriculum document, designed by a K-12 curriculum committee, that clearly defines what is to be taught at each grade level. It is developmentally based, identifies learner outcomes, and provides for periodic evaluation and updating.
____	____	2. The Board of Education receives periodic briefings on the status of the science program.
____	____	3. The development of the science program is influenced by research findings, current trends in science education, assessment of progress in science education (state and national), outside specialists in science education, national curriculum development projects, etc.
____	____	4. Periodically, e.g., every five years, the curriculum for each content area and/or grade level K-12 is reviewed by an external audit team. The observations and recommendations of this team are used by the K-12 curriculum committee to make decisions about the science education program.
____	____	5. The results of this external evaluation are communicated to the science faculty and are used in considering and making program changes.
____	____	6. The science curriculum is coordinated from grade to grade.
____	____	7. Enrichment activities for exceptional children are available for students of all abilities, e.g., individualized learning materials.
____	____	8. The science program consists of four interdependent parts: knowledge or knowing (e.g., What do I know? What is the evidence?), implications for action (e.g., What do I infer? What can I do with what I know? What are other possible interpretations?), prediction of consequences (e.g., What would happen if...?), and the analysis of values (Do I care? Does anyone care?).
____	____	9. There are opportunities for students and teachers to have a voice in the science program and classroom activities.
____	____	10. The science program has been adapted to take advantage of particular local needs, conditions, and resources.
____	____	11. Concepts are encountered repeatedly throughout and across the curriculum.
____	____	12. Our school offers different levels of science instruction to meet the needs of students of different abilities.

____ ____ 13. The instructional materials teach concepts through the use of the learning cycle, i.e., *concept exploration*, in which students explore a concept, discuss observations and ask questions using preselected science objectives or systems; *concept explanation*, in which students are introduced to the concept used to explain what they have explored; and *concept application*, in which students may discover new uses for the concept and application in other situations.

____ ____ 14. Special education students are mainstreamed into regular science classes.

____ ____ 15. Suitable curriculum activities, materials, and instructional strategies have been developed for mainstreamed special education students.

____ ____ 16. Gifted students are provided with challenging materials and independent activities above and beyond the regular class materials.

____ ____ 17. The curriculum contributes to an understanding of the nature, potential and limitations of science, e.g., the natural world (or universe) in intelligible, causal, and not capricious in nature.

____ ____ 18. The curriculum chosen for study through school contributes substantially to understanding the nature of the subject area of science.

____ ____ 19. The curriculum is personally relevant and applicable to the individual's well being, understanding of self, and quality of life.

____ ____ 20. The curriculum is useful in potential cause perception.

____ ____ 21. The curriculum contributes to social decision making with particular emphasis on science-technology-society-based issues.

____ ____ 22. Girls and minority students are encouraged to continue with science throughout their schooling.

____ ____ 23. The curriculum plan clearly describes the education beliefs and assumptions of those responsible for science instruction.

____ ____ 24. The curriculum plan describes why students should study science.

____ ____ 25. The instructional objectives in science are communicated to students and parents.

____ ____ 26. In our science program, we have decided what kind of science education is most appropriate for all our students and for what reasons.

Comments:

FACILITIES AND LABORATORY SAFETY

OVERVIEW

This section is divided into three parts: 1) Elementary, K-6, 2) Secondary, 7-12, and 3) Elementary and Secondary, K-12. The first part is to be completed by the elementary curriculum committee, the second part by the secondary curriculum committee, and the third part by both committees. There are two subsections in each part: A) Facilities; and B) Laboratory Safety.

Directions

1. In the blanks provided in front of each item *or* on the matrix provided, indicate whether the item OUGHT (O) to be achieved and whether it IS (I) achieved in your school/district. Use the rating scales described in "A User's Guide to a Matrix Assessment" **(pg.11)**. If you use the matrix, be sure to label and number the items.

2. Review and discuss your individual responses with another person, then in groups of four, eight, and so on until the entire group has reached agreement on the statements. At each step, you can add to the list of statements, combine, modify, or omit statements. The large matrix provided may be especially useful as the group becomes larger.

3. The space under the Comments heading is to be used to describe additional information needed, to clarify or amplify items in the checklist, to explain judgments and ratings, questions raised, and most importantly, evaluative comments and implications for the science education curriculum/program in your school.

ELEMENTARY, K-6

A. Facilities

O I

____ ____ 1. Our classrooms are equipped with running water, sinks, and sufficient electrical outlets.

____ ____ 2. Our classrooms have adequate storage areas for science equipment and materials.

____ ____ 3. There is an "outdoor classroom," an environmental educatin area on the school grounds that can be used for nature study, environmental science investigations, garden project, etc.

Comments:

B. Laboratory (Classroom) Safety

O I

____ ____ 1. Teachers instruct the students in safety procedures at the beginning and throughout the year.

____ ____ 2. All safety equipment is checked each year and replaced as necessary.

____ ____ 3. Students are tested about safety apparatus and procedures from the beginning of the year.

____ ____ 4. Provision is made for children to have washing materials available when chemicals are used.

____ ____ 5. Plastics are substituted for glassware in all of our laboratory work.

____ ____ 6. Children are instructed not to taste anything during a science activity.

____ ____ 7. When using a heat source, students are instructed to maintain a clear working area, to button and/or roll up loose sleeves, and to tie back long hair.

____ ____ 8. When students are involved in activities which use a heat source, a bucket marked "FIRE" is placed in an accessible place in the classroom. It is filled with water or sand.

____ ____ 9. When students are involved in activities which use a heat source and chemicals, students and teachers wear safety goggles.

____ ____ 10. Strong acids and alkalies are not used in our program.

Comments:

SECONDARY, 7-12

A. Facilities

O I

____ ____ 1. Science classrooms and laboratories are adequately equipped and maintained for the conduct of our program.

____ ____ 2. When working with chemicals, safety goggles are mandatory for students, teachers, and classroom visitors.

A. Facilities (con't)

O	I	
____	____	3. Any poisonous substances are stored in a secure (locked) area or a poisons cabinet.
____	____	4. All reagents are clearly labeled by formula and name. In addition, appropriate warnings are included on the lable: flammable, allergen, volatile, acid, base, irritant, toxic, etc.
____	____	5. Students are routinely instructed on how to "turn-off" an experiment safely at any stage, e.g., during a fire drill in the middle of a laboratory session.
____	____	6. Shielding for both teacher and students is provided for demonstrations involving the possible explosion or implosion of apparatus or the possibility of injury due to chemical splattering.
____	____	7. Adequate supervision of the laboratory is provided at all times.
____	____	8. Chemicals are purchased in quantities such that they will be used in a reasonable and safe period of time. Chemicals are dated when received.
____	____	9. Smoke detectors have been installed in the chemical stores area.
____	____	10. Laboratory rules are prominently posted in all laboratories.
____	____	11. Electrical outlets in the science laboratories are properly grounded.
____	____	12. Chemicals are not stored in classrooms.
____	____	13. Master cut-off controls for water, gas, and electricity are available in a central area.
____	____	14. Chemicals are stored in compatible families, *not* alphabetically.
____	____	15. Science teachers have completed approptriate first aid training.
____	____	16. There are clearly labeled fire extinguishers for all classes of fires.
____	____	17. Science teachers have received training in how to use a hand-held fire extinguisher.
____	____	18. The science department has up-to-date resource books on school science safety and manuals listing potentially hazardous substances.
____	____	19. No food is allowed or stored in the laboratory, including especially the laboratory refrigerator.

A. Facilities (con't)

O	I	
___	___	20. A student safety contract that details the safety requirements and expectations of the school and the relationship of these policies to the students is required. Students are expected to read and sign the contract which signifies that they have been instructed in the requirements for safety in the school laboratory.
___	___	21. Students are required to take and pass a safety test before they can participate in laboratory work.
___	___	22. Safety-related questions are included on quizzes
___	___	23. Chemistry laboratories are adequately ventilated and equipped with fume hoods.
___	___	24. Fume hoods are not used to store chemicals.
___	___	25. Safer alternatives that will accomplish the same purpose have been substituted for laboratory experiments involving toxic or other wise hazardous or potentially hazardous substances.
___	___	26. Some experiments for which there is not a safe alternative have been elimated from our program.
___	___	27. Films or videotapes of dangerous chemicals reactions are shown as a substitute for certain chemical reactions.
___	___	28. Mercury thermometers have been replaced with non-mercury types.
		29. Safety equipment is available in sufficient quantities for students.
___	___	30. Safety equipment is provided in the science laboratory, e.g., eye wash solutions, safety shower, fire blanket, fire extinguishers, broken glass container, sand bucket on the floor.
___	___	31. When experiments are introduced, students review any necessary safety training related to the work.
___	___	32. Whenever new equipment is introduced to students, appropriate safety rules are discussed and reviewed.
___	___	33. The science teachers have participated in a workshop on chemical and laboratory safety.
___	___	34. The use of contact lenses in the laboratory is actively discouraged.
___	___	35. The science department has developed a letter to parents informing them of potential hazards, safety training and procedures, and the need for their children to obey rules.

A. Facilities (con't)

O	I	
____	____	36. Each year (or periodically), a knowledgeable member of the science staff is designated as the manager of chemical storage areas.
____	____	37. Acids are stored away from other items in a dedicated storage area, preferably a locked cabinet. Nitric acid is stored separately unless there is a special compartment in the cabinet.
____	____	38. Flammables are stored in a dedicated locked and vented cabinet.
____	____	39. The gas/air/water outlets are both labeled and distinguishable one from another.

Comments:

ELEMENTARY AND SECONDARY, K-12

A. Facilities

O	I	
____	____	1. Overall, the science facilities–classrooms, laboratories, and special spaces/places–are well suited for our science program. They have adequate storage areas, are appropriately equipped, and are maintained on a routine basis.

Comments:

B. Laboratory Safety

O	I	
____	____	1. The science department and science program is in compliance with Minnesota's Employee Right-to-Know Law. This includes: 1) setting up an initial, pre-assignment, and annual training and information program; 2) an inventory of hazardous substances and agents in the workplace; 3) identification of employees who may be exposed; 4) establishing a written information system; and 5) maintaining material safety data sheets (MSDS) and information systems on harmful physical agents, and infectious agents; a labeling system for hazardous substances.

B. Laboratory Safety (con't)

O	I	
______	______	2. A list of national, state, and local emergency telephone numbers is posted near the teacher's desk or work area. Key numbers include: fire dapartment, physicians or hospital emergency room, poison control center, police, and rescue squad.
______	______	3. The school/school district has a safety policy which is approved by the department, principal, and the central administration.
______	______	4. The school/school district has an accident procedure and a process for recording and reporting an accident.
______	______	5. A safety audit of all science facilities is conducted each year.
______	______	6. All safety hazards are reported to the principal in writing.
______	______	7. A plan has been developed and is followed for the safe removal of excess and/or old and/or hazardous chemicals.
______	______	8. *General* safety procedures and guidelines have been developed for the science laboratory.
______	______	9. *Specific* safety procedures and guidelines have been developed for working with microorganisms, plants and animals, chemicals, electricity, and lasers.
______	______	10. Teachers are familiar with the code of practice on using animals in, the classroom published by the National Science Teachers Association.
______	______	11. Alcohol burners are not used in our school.
______	______	12. The risk of all experiments and demonstrations have been taken into account. The written assessment includes: ability level of students, general safety features of the laboratory/classroom, hazards involved with the experiment, provisions for disposal of substances produced, toxicity level of products and reactants, documentation, and whether a safer alternative is available.
______	______	13.First aid kits are available in all science classrooms and laboratories.

Comments:

THE SCIENCE EDUCATION CURRICULUM

Overview

This section is divided into three parts: 1) Elementary, K-6, 2) Secondary 7-12, and 3) Elementary and Secondary, K-12. this first part is to be completed by the elementary curriculum committee or teachers and the third part by **both committees.** The elementary and secondary checklist are further subvdivided into three parts: A) Curriculum Planning; B) Classroom; and C) Evaluation.

Directions

1. In the blanks provided in front of each item or on the matrix sheet provided, indicate whether the item OUGHT (O) to be achieved and whether it IS (I) achieved in your school/district. Use the rating scales described in "A User's Guide to a Matrix Assessment" (**Pg.11**) If you use the matrix, be sure to label and number the items.

2. Review and discuss your individual responses with another person, then in groups of four, eight, and so on until the entire group has reached agreement on the statements. At each step, you can add to the list of statements and combine, modify, or omit statement. The large matrix provided may be especially useful as the group becomes larger.

3. The space under the comments heading is to be used to describe additional information needed, to clarify or amplify items in the checklist, to explain judgments and ratings, questions raised, and most importantly, evaluative comments and implications for the science education curriculum/program in your school.

ELEMENTARY, K-6

A. Curriculum Planning

O	I	
____	____	1. Our school has a grade K-6 curriculum document which specifies long-range goals and short-term objectives for each grade level.
____	____	2. The grade K-6 curriculum document specifies and describes the science experiences for all grade levels. It includes both required and optional units of instruction.
____	____	3. One of the curriculum goals in the plan is to stimulate enthusiasm for the study of science.
____	____	4. Another curriculum goal in the plan is to help students gain an understanding appropriate for their age of a *few* basic science concepts.
____	____	5. The curriculum plan clearly lists concepts skills, scientific attitudes, and attitudes toward science to be developed by students.

_____ _____ 6. The curriculum plan clearly lists concepts and skills that should be fostered in students. About attitudes, it says that students should develop their own personal preferences and attitudes toward science.

B. Administrative Support

O I

_____ _____ 1. The procedure for ordering materials and equipment is efficient and sufficiently flexible.

_____ _____ 2. Authorization to purchase supplies and materials locally is easily obtained when there is a justifiable reason for the request.

_____ _____ 3. The school/school district employs an elementary science supervisor/consultant.

_____ _____ 4. The school/school district employs a science resource teacher.

Comments:

SECONDARY, K-12

A. Budget

O I

_____ _____ 1. The science budget is sufficient to allow the purchase of all supplies and materials that are needed for a laboratory, inquiry-based program.

_____ _____ 2. The science department is involved in the development of the budget.

_____ _____ 3. The science department has developed a mutually agreed upon list of major purchases indicating their priorities.

_____ _____ 4. There are petty cash funds or teachers are reimbursed when it is necessary to purchase special materials for science throughout the school year.

_____ _____ 5. There is a budget for maintaining equipment on a regular basis.

_____ _____ 6. The staff knows how much it costs to educate a child currently in science.

_____ _____ 7. There is a budget sufficient for at least one science-related field trip each year in each science course.

_____ _____ 8. There is a budget for support of extracurricular activities, e.g., participation in the Minnesota Science Challenge, science clubs, and science fairs.

A. Budget (con't)

O I

____ ____ 9. The science department is current and active in seeking available local, state, and federal sources of funds.

Comments:

B. Administrative Support

O I

____ ____ 1. The procedure for ordering materials and equipment is efficient at sufficiently flexible.

____ ____ 2. Authorization to purchase supplies and materials locally is easily obtained when there is a justifiable reason for the request.

____ ____ 3. There is a science department chair.

____ ____ 4. The school/school district employs a full-time secondary science supervisor.

Comments:

ELEMENTARY AND SECONDARY, K-12

A. Budget

O	I	
____	____	1. The budget for science is a line item in the total school budget.
____	____	2. During period of financial stress, teachers in the science program are asked to make recommendations for plans to make immedicate cuts.
____	____	3. If a protracted period of financial stress is projected, teachers in the science program are asked for their recommendations and their implications.
____	____	4. In establishing the budget for science, K-12, a committee of elementary and high school teachers use a weighted formula to prioritize the needs and decide how the money will be spent.

Comments:

B. Administrative Support

O	I	
____	____	1. There is administration support in terms of time, money, and inservice for the development of a science program that meets the needs of all students, e.g., gifted, special needs and, in high school, so called academic and non-academic students.
____	____	2. Teachers are involved in the development of inservice programs.
____	____	3. Release time is provided for teachers to attend local, regional, state, or national conferences or seminars or to visit outstanding science programs in other schools.
____	____	4. There is a fair and reasonable rotating schedule for staff members who want to attend local, regional, state, or national science education activities.
____	____	5. The school covers all or a significant portion of a teacher's expenses to attend professional activities.
____	____	6. The school/school district employs a K-12 science supervisor/consultant.

B. Administrative Support (con't)

O	I	
___	___	7. The school/school district employs a K-12 curriculum supervisor/ consultant who spends 25 percent of her or his time on science.
___	___	8. The school/school district employs a K-12 science resource teacher.
___	___	9. The administration actively supports the development of grant proposals from local, state, and national sources for the development of curriculum and science program innovations and improvements.
___	___	10. The administration actively supports the formation of "local alliances" new partnerships and action groups of scientists, engineers, and science educators joined with representatives from business, labor, and community service groups in support of science and technology education.
___	___	11. There is a broad-based community supported equipment loan and repair program which is used to support the science program that includes temporary as well as long-term loan arrangements. It includes, where necessary, instruction on how to use the equipment (and sometimes, equipment that may already be in the school stockroom).
___	___	12. The administration regularly provides time and opportunity for K-12 planning and curriculum development which involves a variety of teachers and others throughout the school district.
___	___	13. The K-12 budget for science is realistic and adequate for the science program.
___	___	14. There is a budget for honoraria to defer some of the expenses for consultants, workshop leaders, and others.
___	___	15. There is an active ongoing sabbatic leave program that pays teachers either their full salary or partial salary.
___	___	16. Help and support-money, time, and services-is given teachers after planning and initial training over a fairly long time.
___	___	17. There are stipends for teachers to pay for work beyond the school day or in the summer.

Comments:

LEARNER OUTCOMES: WHAT SHOULD BE LEARNED

Overview

Learner outcomes are carefully selected samples of knowledge statements considered as some essential learning outcomes for students. Learner outcomes are statements of expectation for science education. The outcomes stated below were developed and categorized by a team of Minnesota science teachers and curriculum specialists. They are intended as a guide to aid in assessment and evaluation -- a status check on where the science program is, review, and local school district curriculum planning. This includes selection of goals/objectives, determination of the scope and sequence of the science program, implementation considerations -- the means to achieve science education goals and objectives, evaluation strategies, and a written plan.

The list of learner outcome examples is neither exhaustive nor prescriptive. It is understood that the scope of expectations for science is plentiful. We selectively focused on a few important ideas that encompass elementary and secondary school science. The focus and debate of our group has been on the fundamental rather than what is nice but secondary. Users of this guide will no doubt have valid modifications, preferences, and priorities of their own.

This de-emphasis, if you will, of factual knowledge in science to that knowledge which is considered essential, is consistent with other themes in this guide. This focus on teaching what is essential is also the basic premise of Project 2061: Science for all Americans, the set of recommendations on scientific literacy by the American Association for the Advancement of Science. After choosing content, a major task in science education today is in helping young, inexperienced learner to learn to use it. We believe this is best done when, to use the words of Arnold Arons, the science curriculum "is experientially rooted and not too rapidly paced." In other words, it takes time to learn to use science content in order to know it.

The translation of goals and objectives for science education into specific grade level and subject matter or curriculum content is a local school district affair. It should include broad representation from the science educators in that school or system as well as, where appropriate, other "stakeholders" who have views about the school curriculum and who desire to influence decisions about it." "Stakes" in the science curriculum are held not only by science teachers but also by parents, school administrators, as well as other groups and institutions in the community.

It is suggested that, as a part of a local planning process, the science learner outcomes be very carefully examined. Local schools/school systems are encouraged to select what is good and consistent with their previously stated goals and reject any learner outcome material that is not congruent or to substitute/develop their own science learner outcomes.

Once learner outcomes have been carefully evaluated locally and/or supplemented in a way that is consistent with local broad-range goals, then the science education curriculum can be selected, implemented, and evaluated. Evaluation is a process for determining if expectations are being met. This includes, of course, testing students for grading purposes, i.e., focusing on the achievement of student learning outcomes. It also includes program effectiveness, i.e., focusing on the quality of the entire science education program. These kinds of evaluation can be conducted using local criteria, something that is difficult, if not impossible, using commercial standardized materials.

It is obvious that no single sequence of activities will fit all curriculum implementation efforts. On the contrary, a particular sequence of implementation activities will depend on many variable. These include: the level at which the curriculum is to be implemented; the school district's commitment in time and money; assignment of personnel, material resources, and facilities; the ability, willingness, and opportunity of those involved to fully participate; the students to be served and what is known about them; staff experiences and attitudes toward children, education, and science-in fact, all attitudes and rules, explicit or implied, that govern the schools and communities regarding curriculum.

The purpose of science curriculum improvement is to benefit students. Achievement of this goal will not occur by mandate nor quick action. Since world views, both individual and collective, determine, or at least influence, the nature of every transaction which takes place during a human activity such as curriculum implementation, the participating staff and others should be aware of the various world views that influence the identification of issues. What are the problems? What are the facts? Where do we go from here? It is to be expected that the educational priorities of the individuals and groups involved in the work will be very diverse, and correspondingly, it can be expected that a dogmatic approach to curriculum development will result in a lack of commitment of everyone involved. Ownership and commitment will not be immediate. Like the development of trust, they develop over time and through the work associated with improving the effectiveness of a science education program.

High on any agenda for improving science education programs is reaching agreement on the basic outcomes, or expectations or the terminal goals of science education-the list of skills, knowledges, and attitudes to be learned by the student, all finely tuned and interrelated. This is the what of science eduation. What content is important and where, level and/or subject matter area, should it be taught? These considerations lead to the organization of the science curriculum, e.g., the relationship between laboratory and content, a unified approach, a special curriculum, or a strict scope and sequence.

Every course, unit, daily lesson plan, or individual learning experience should be related to the terminal goals of science education. The work is difficult but not an impossible task. Because of differences between individuals, making decisions in the early stages will involve negotiation. You will have to decide whether there will be a vote with a plurality decision, or whether consensus is desired. The overall goal is the establishment and/or maintenance of a new science education curriculum program or a permanent course of study. It is important to reach a decision that is as widely supported as possible, or, at least, not actively opposed.

From the perspective of the discipline, learner outcomes for science education have been subdivided into: 1) Elementary, 2) life science, 3) earth science, 4) physical science, 5)biology, 6) chemistry, and 7) physics. In addition, learner outcomes are also indluded for these components of science education: 8) Science, Technology, and Society, 9) Science for Personal Needs, 10) Processes of Science Education, and 11) Science Attitudes and Values.

LEARNER OUTCOMES: Instructions

A matrix sheet has been provided in order to help you rate each learner outcome from the perspective of your level or science discipline. Initially, you will be asked to look at each outcome, and from the point of view of your level/discipline assign a number from -1 to 4 in both the **IS** and **OUGHT** columns.

OUGHT to be achieved in the Science Education Program

5 -of utmost value
4 -of significant value
3 -of medium value
2 -of insignificant value
1 -of negative value

IS achieved in the Science Education Program

5 -extremely high level
4 -above average
3 -on the average
2 -less than average
1 -avoided or non-existent

If you used a matrix to record your evaluations, use the graphical interpretation of the data to assist you in making the following decisions.

a). Grade level/subject. In the row of cells (following pages), use one of the following symbols to indicate the degree a learner outcome should be stressed:

I - Introduce	This represents the first time a topic will be presented as a part of a classroom activity.
M - Maintain	Review and reinforcement of learner outcomes previously introduced at an earlier level.
E - Emphasize	This is a learner outcome that is to be stressed in a unit of instruction. It is an outcome of concern and importance in teaching science at a given level or in a particular course of study.
N -	Not covered or applicable at this level of instruction or science course.

b). Adoption. In the space that says: **ADOPTION YES NO,** indicate whether the learner outcome should be adopted. Obviously, this should be done for those outcomes that are not currently a part of the curriculum.

c). For each cluster of outcomes, there is space provided under the heading, Comments, to be used to add learner outcomes or to describe additional information needed, to clarify or amplify items in the checklist, to explain judgments and ratings, questions raised, for any evaluative comments, and implications for the science education curriculum/program in your school. The task force will appreciate and use this information in making final decisions about the selection of outcomes.

LEARNER OUTCOMES
A CHECKLIST

CONCEPTS

O	I	CAUSE/EFFECT	K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
		Support concept that all things in nature are caused by a natural force.								
		Human activity affects the global environment positively and/or negatively.								
O	I	CHANGE								
		Cite examples indicating that show that the Universe is in constant change.								
		Describe change by comparing the final state of a system or organism to its initial state.								
		Cite evidence that all life has evolved in response to a changing environment.								
		Classify changes as chemical, physical or nuclear.								
		Identify and predict changes of state.								
O	I	CYCLES								
		Recognize patterns where certain events or conditions seem to be repeated at regular intervals or periods.								
O	I	ENERGY/MATTER								
		Define energy as the ability to do work.								
		Define matter as that which composes all things.								
		Understand that energy and matter are conserved.								
		Describe the nature of energy transformation within a given system.								
		Describe applications of the electro-magnetic spectrum.								

O	I	EQUILIBRIUM AND HOMEOSTASIS	K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
		Predict effects of external forces on a system at equilibrium.								
		Recognize a system in equilibrium.								
O	I	INTERACTION								
		Cite examples where two or more things influance one another.								
O	I	FUNDAMENTAL ENTITIES								
		Define fundamental units of abiotic systems.								
		Define fundamental units of biotic systems.								
		Explain operations of a system in terms of its fundamental units.								
		Cite evidence that matter is made up of particles.								
		Identify the fundamental unit of a given system.								
O	I	PROBABILITY								
		Calculate the relative frequency with which an event occurs in an indefinately large number of trials.								
		Demonstrate that probability cannot determine or describe the occurance of a specific event.								
		Identify uses of probability to predict occurances in nature.								

O	I	PATTERNS AND SYMMETRY	K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
		Cite evidence that most events in nature follow patterns.								
		Students discuss various forms of symmetry in nature.								
O	I	SYTEMS								
		Demonstrate that a system is a group of interacting components.								
		Describe a system in terms of being open or closed.								
		Understand the total system when solving problems.								
O	I	**BASIC PROBLEM SOLVING SKILLS** OBSERVING								
		Employ all the senses to collect information concerning objects, systems, and events.								
		Distinguish observations from inferences.								
		Use specific tools in an appropriate manner which extend the senses (e.g., microscope, hand lens, stethoscope to make observations.								
O	I	INFERRING								
		Examine observational data, and select the most likely judgement, conclusion or explanation.								
		Draw a conclusion from data displayed on a variety of graphs and charts.								
		Make reasonable inferences concerning the characteristics of an object, system, and/or event.								
		Realize that inferences based on observations are tentative and subject to change with new data.								

O	I	CLASSIFYING	K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
		Impose order on collections of objects or events based on physical or chemical properties.								
		Develop chemes to differentiate specific objects, systems, or events from a collection using valid criteria.								
		Develop classification systems that can be used by other people, to reliably get the same results.								
		Understand that classification systems are arabitrary and may change with different classification criteria.								
O	I	MEASURING								
		Use a variety of conventional and international units to quantify scientific phenomena and/or events.								
		Use these common tools of science to measure objects and events; computer probeware, balance, thermometer, meterstick, teimepiece, graduated cylinder.								
		Know that several measurements can be averaged in order to reduce error.								
		Produce objects or events of a specific size and or magnitude of objects or events.								
		Know that each method of measurement has inherent error.								
O	I	USING TIME/SPACE RELATIONSHIPS								
		Describe events over time such as seeds growing or eggs hatching.								
		Describe biological succession in terms of population's response to environmental changes.								
		Describe an object in reference of another object.								
		Be able to place objects in serial order.								

O	I	PREDICTING	K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
		Make a reasonable accurate forecast.								
		Recognize that predictions are not random guesses, but based on patterns identified from previous observations, measurements and models.								
		Make predictions from a graph.								
		Change a prediction in light of new facts.								
O	I	USING SCIENTIFIC, MATHEMATICAL SYMBOLS								
		Will be able to construct, read and interpret information in symbolic form (graphs, tables, and charts) using scientific symbols and conventions.								
		Understand scientific notation--magnitude, size.								
		Manipulate mathematical formulas and expressions to solve problems.								
O	I	INTERPRETING DATA								
		Identify patterns or regularities in a set of data.								
		Determine data significant to a laboratory investigation.								
		Distinguish qualitative data (information) from quantitative data.								
		Use experimental data to establish algebraic relationships among variables.								
O	I	COMMUNICATING								
		Organize information and data in such a way that others can understand it.								
		Describe an event or prodcedure using appropriate scientific terms.								

O	I	COMMUNICATING (CONT'D)	K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
		Produce a summary of an investigation which is concise, accurate and logical.								
		Use a variety of methods to communicate collected data such as computer programs, graphs, tables and charts.								
O	I	FORMULATING HYPOTHESES								
		Demonstrate the ability to make a testable idea for something observed or inferred.								
		Understand that any hypothesis is subject to a fair test.								
O	I	IDENTIFYING AND CONTROLLING VARIABLES								
		Recognize that a variable is a condition that may influence the outcome of an investigation.								
		Identify and control variables that may influence an outcome or reaction.								
		Classify a variable as controlled, manipulated and responding.								
O	I	SCIENTIFIC MODEL BUILDING AND USE								
		Are able to cite and employ models from a variety of scientific disciplines.								
		Compare and contrast various scientific models								
		Know that models are created to explain and predict natural phenomena.								
		Understand that scientific models are subject to change.								
		Critically examine a model and examine its limitations.								
		Create a model that explains a phenomenon.								
O	I	EXPERIMENTING								
		Design a fair test for a hypothesis.								
		Respect and adhere to safe laboratory procedures when conducting an experiment.								

C. PERSONAL NEEDS

O	I	ATTITUDES TOWARD SCIENCE	K-3	4-6	Life Science	Earth Science	Physical Science	Biology	Chemistry	Physics
		Distinguish scientific ways of knowing from other ways of knowing.								
		Contributions that men and women have made to science.								
		Access to science careers not related to gender, cultural diversity or handicaped condition.								
O	I	**D. SCIENCE IN THE WORLD** SCIENCE/TECHNOLOGY/SOCIETY								
		Recognize and cite examples of trade offs implicit in the resolution of a societal issue.								
		Illustrate the integration and interdependence of science and society.								
O	I	**E. READING AND WRITING IN THE SCIENCES**								
		Ability to access information from and through various media sources.								
		Ability to analyze and evaluate sources of information, validity of claims and biases of sources.								

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